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Study of certain

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Gigartina stellata,
Chondrus crispus,
agar testing
Agars,



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A STUDY OF CERTAIN
BRITISH SEAWEEDS
AND THEIR UTILISATION IN
THE PREPARATION OF
AGAR

by

S. M. MARSHALL, L. NEWTON and A. P. ORR

with the collaboration of

P. W. CARTER · E. CONWAY · K. M. DREW · E. A. LEWIS
J. MACNAUGHTAN · H. T. POWELL
AND OTHERS

Edited by L. NEWTON

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Study of certain

FOREWORD

BY LT.-GENERAL SIR ERNEST BRADFIELD, K.C.I.E., O.B.E., I.M.S.

Chairman, Vegetable Drugs Committee, Ministry of Supply

It is with considerable pleasure that I write this foreword. Both as a member of the Vegetable Drugs Committee and as its Chairman I have watched this wartime task from its commencement with a great interest that was shared by Sir Weldon Dalrymple Champneys Bt., M.A., K.H.P., D.M., B.Ch., who preceded me as Chairman of the Committee.

A shortage of agar during the war would probably have meant the breakdown of our public health services and would have had far-reaching and serious results, so that the work undertaken by Professor Lily Newton and her scientific helpers, all of whom worked on an entirely voluntary basis and sacrificed the vacations from their Universities that the work might be completed, is deserving of the highest praise.

A comprehensive study of the autecology of *Gigartina stellata* Batt. has never been attempted before and this monograph, therefore, should be of permanent academic value.

ERNEST BRADFIELD

FORWORD

It is a pleasure to have this book published in the form of a book. The author has been very kind to allow me to write the foreword.

It is with a sense of responsibility that I write this foreword. I am a member of the American Library Association and as such I have a duty to the public to write this foreword. I have written this foreword in the hope that it will be of some use to the reader. I have written this foreword in the hope that it will be of some use to the reader.

A library is not a place where books are kept. It is a place where books are used. It is a place where books are read. It is a place where books are shared. It is a place where books are loved. It is a place where books are used to learn, to grow, to live. It is a place where books are used to make a better world.

It is a pleasure to have this book published in the form of a book. The author has been very kind to allow me to write the foreword.

Forrest B. Smith

AUTHORS' PREFACE

THE fact that agar is indispensable in the preparation of bacteriological media made it desirable that all belligerent countries should have a local source of this substance. In the early days of the war therefore, preliminary investigations were made on the suitability and distribution of certain red seaweeds in Britain. Subsequently *Gigartina stellata* Batt. and *Chondrus crispus* (L.) Stackh. were selected for detailed investigation and the Ministry of Health and later the Vegetable Drugs Committee of the Ministry of Supply gave us full support to carry out and extend the work. We offer to them our grateful thanks for financial and administrative assistance.

The botanical work was under the direction of Dr. Lily Newton, Professor of Botany, University College of Wales, Aberystwyth and the chemical work was carried out by Dr. S. M. Marshall and Dr. A. P. Orr, both of the laboratory of the Scottish Marine Biological Association, Millport, Isle of Cumbrae, Buteshire. We wish especially to acknowledge the facilities afforded us by the respective institutions with which we are associated.

Dr. E. A. Lewis carried out much of the ecological shore work, especially in Wales; Dr. E. Conway undertook shore and laboratory work on the Cumbrae; Mr. P. W. Carter was responsible for the work in the south-west of England, and Dr. K. M. Drew was responsible for the cytological work. Appendix I was written by Mrs. MacNaughtan (University of Edinburgh), Dr. V. D. Allison and Dr. B. Hobbs (Emergency Public Health Department, Ministry of Health, Cardiff), who were responsible for the testing of the product from the early stages of the work. Mr. H. T. Powell has given invaluable assistance in the preparation of the material for the press.

Additional notes and Tables are contained in the Ministry of Supply Permanent Record Monograph No. 11,145, copies of which are held in the Directorate of Chemical Research and Development, Shell Mex House, London.

We wish also to thank numerous workers, some of whom are listed in the text, and others on pages 97 and 103-104. Much of the earlier ecological work on *Chondrus crispus* (L.) Stackh. was carried out on the Gower coast by Miss Doreen Richards, whose help we gratefully acknowledge. We wish also to express our thanks to Mr. E. H. Chater, for experimental investigations relative to harvesting, as well as for assistance with the survey. Observations on the ecology, life-history and cytology of *Gigartina stellata* Batt. are being continued.

June 1947

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A STUDY OF CERTAIN BRITISH SEAWEEDS AND THEIR UTILISATION IN THE PREPARATION OF AGAR

INTRODUCTION

AGAR is an extract from certain seaweeds, which dissolves in water and sets to a firm jelly. Up to 1939 most of it was obtained from Japan (Dickover, 1927), where it had been known for centuries (Newton, 1945), the total production amounting to over 2,000 metric tons per annum. The weed from which the best agar was prepared before 1939 was *Gelidium corneum*; other agars were prepared from different *Gelidium* spp., *Gracilaria* spp., *Eucheuma* spp. and other red seaweeds (Hoffman, 1939)*. It must be realised that the term *Gelidium corneum* has probably been used in a composite sense, and is likely to have covered more than the type species.

In times of peace, before 1939, agar was used for a great variety of purposes. It is unrivalled as a medium for the growth of fungi and bacteria and in this respect it has great advantages over animal gels. It is not liquefied by many organisms which cause liquefaction of a medium containing animal gelatine, and it has a firm rubbery surface which is not easily ruptured when stroked with an inoculating needle. Agar remains liquid when cooled to 40° C., so that organisms can be readily mixed with it at a temperature of 45° C., which does not harm them. It changes readily from sol to gel state, or vice versa, on being subjected to change of temperature. Another property of agar is that it forms a firm jelly without refrigeration, and remains solid at 37° C. It will withstand high pressure for a certain length of time without undergoing hydrolysis.

The use of agar revolutionised the study of bacteriology. Previous to its application to that science, bacteria and fungi were studied when growing on broths or on a gelatine medium, the latter being a method introduced by the bacteriologist Koch (1881). While he made great advances in the study of bacteriology, Koch recognised the defects of gelatine. It was, however, Frau Fanni Eilshemius Hesse, wife of Walther Hesse, an eminent bacteriologist, who first introduced agar as a culture medium into her husband's laboratory. According to Hitchens and Leikind (1939), she obtained from her mother a recipe which had come originally from a Dutch family living in Java, where Japanese agar made from *Gelidium corneum* was used domestically. She may have used a Japanese agar, or it may be, as is suggested by Tseng (1944a) that an East Indian agar from the seaweed *Eucheuma muricatum* was the original agar culture medium. In either case, the recipe was

destined to be of universal application in bacteriological study all over the world.

Some of the physical properties already mentioned have been responsible for the important position of agar in the food and drug industries. Agar was used extensively in medicine and pharmacy. Unlike pectin, it needs no sugar to make it gel. It was used in conjunction with gum arabic or a like preparation as a protective colloid in petroleum-agar emulsion. Taken into the alimentary canal, the agar swells, but is not digested (Saiki, 1906). It furnishes a large volume of faecal matter, and without causing chemical irritation, it gently stimulates intestinal action. It does not remain in the acid medium of the stomach long enough to be hydrolysed, and in the alkaline intestinal fluid no hydrolysis takes place.

Agar was also used as a glycerine substitute, a pill excipient, an ointment base, and as a wound dressing, the last because of its water-absorbing capacity and inhibitory action on blood clotting. It has been used to stabilise an emulsion to carry vitamins (Tseng, 1944a). Agar was used in the manufacture of plastic material suitable for making dental imprints, for which it was particularly suitable because of the time-lag between melting and setting points. It is also said to have been used to take the moulds for making artificial hands (Tseng, 1944b).

The food industry made considerable claims on the world's agar output. In addition to its very considerable use in the Orient in the preparation of food and delicacies, agar also formed 'bulk' in the manufacture of diabetic foods. It was widely used in canning meats and fish, especially the latter, because the firm jelly was especially suitable as a medium in which the soft tissues of cooked fish could be transported. It is also said to prevent the detinning action which some kinds of fish have on the can (Gamage, 1922). Patents were granted for making dehydrated and powdered fish extract with agar for use in soups and flavouring preparations (Tseng, 1945a). It provided the gel in all kinds of meat pies, and from it artificial sausage skins were also made. As a thickening agent in creams, puddings, ice-cream, salad-dressings and soups, agar was used extensively in America. It had a considerable use in confectionery, where it formed a base which was variously flavoured and sold as a sweetmeat, often being coated

*Further information on the Japanese agar industry may be obtained from Report No. B.I.O.S./J.A.P./P.R./814, H.M. Stationery Office, London.

with chocolate. It was used as a clearing agent for wines and beers. It was also used in making a cream cheese of the Neufchatel type (Dahlberg, 1927; Marquardt, 1930). On account of its resistance to most putrefying bacteria, agar was also valuable when used as a medium in which meat was cooked for domestic use.

Apart from its use in food, medicine and pharmacy, agar was used in greaseless cosmetics, in creams and soaps, and as an ingredient of Kalsomines, shoe stains, and hand lotions. It has also been used in the manufacture of marine storage batteries (Tseng, 1944b). In the textile and leather trades it formed a sizing medium for fabrics, a thickener in the dyeing and printing of textiles, and was used in the finishing processes of leathermaking. In the hot-drawing of tungsten wire for electric lamps a lubricant is necessary to facilitate the operation and reduce wear on the die. The lubricant has been made from graphite in agar gel (Tseng, 1944a).

Agar was a constituent of various high grade adhesives and was used in the manufacture of plywoods. Films prepared from it were used as windows, and photographic films were prepared from an aqueous solution treated with formaldehyde. These needed to be only one-eighth the thickness of gelatine films (Tseng, 1944a).

It has been used as an activator in nicotine sprays (Sharp, 1939). An aqueous solution, 1 : 500, trebled the effectiveness of the spray for destroying the pea aphid, *Illinoia pisi*. The objection to its general use is the difficulty of dispersing it in cold water, but the use of boiling water to prepare the spray would obviate this handicap. Agar is also used in the preparation of bacterial cultures in humus or peat for agricultural purposes (Tseng, 1946).

Agar has also been used in the electroplating of lead and the sizing of paper, in which latter case it imparts resistance to the penetration of wax or grease.

The food value of agar to human beings is probably very slight (Saiki, 1906). The complex polysaccharide appears to be hardly attacked at all by plant enzymes, by animal digestive juices or by bacteria. Nilson and Schaller (1941) showed that in male albino rats fed on agar, the apparent digestibility coefficient of the nitrogen-free extract of agar was about 28%. There is some indication however of the presence, in agar, of certain growth-promoting substances. Mitchell (1922) records that animals fed on a purely synthetic diet showed faulty growth which disappeared at once when 5% of purified agar was added. Robbins (1939) observed the beneficial effect of agar on spore germination and growth, and also on the formation of gametes and zygotes in the case of *Phycomyces Blakesleeanus*. He found that beneficial material could be extracted from the agar, in part by dilute methyl alcohol and more completely with aqueous pyridine. He too suspected the presence of unknown growth substances in the agar.

Agar is also used as an embedding agent in biological

technique and is used in analytical and colloid research (Tseng, 1946).

Although the manufacture of agar, prior to 1939, was largely a monopoly of the Japanese, attempts had been made in various parts of the world to obtain from red seaweeds a gel that could be used for at least some of the purposes for which, formerly, Japanese agar had been imported.

With the spread of the recent world war, it became increasingly clear that it was necessary for countries to seek a weed known to produce agar or to find a substitute, around their own shores. The necessity arose even before Japan became a belligerent enemy country, in view of the difficulties and hazards of transport, coupled with the vital need for agar as a bacteriological medium for the preparation of vaccines, both for civilian populations and for the armed forces. Agar was also needed for the research which led to the large-scale production of penicillin. It is used for making the medium on which solutions are tested for their penicillin content by the plate and cylinder method. Porous porcelain cylinders containing a penicillin solution are placed in petri dishes on an agar jelly, which latter has been inoculated with staphylococci or other sensitive bacteria. The penicillin solution diffuses out from the porous cylinders and inhibits the growth of bacteria in a zone of varying width, dependent on the strength of the solution (Anon., 1944).

With the attack on Pearl Harbour, the world position became even more acute, and the way in which countries developed their own resources and met, in one way or another, the vital need for agar, is a narrative which gains greatly in interest now that easier communication is established between widely separated continents and the close co-operation of scientists, harvesters and manufacturers can be revealed. It is evident that many of the problems were common to all scientific workers, whatever may have been their source of agar material. The plants used in Japan and elsewhere were red seaweeds and therefore they grew either near low water mark of ordinary spring tides, or at greater depth. Such plants are accessible to shore-collectors only for short periods each day, and if they grow very near to low water mark of spring tides, they are exposed only for a few days each fortnight, when suitable tides occur. In some areas the workers were fortunate enough to have a relatively flat sea-floor where, by means of rakes or other implements, the weed could be obtained when it was not exposed; in other places, the plants grew in sufficiently large quantities to merit the use of divers. There is one record from Australia of a suitable weed growing on sandy estuarine flats and being washed ashore in quantity at a certain season, but such records of the availability of suitable driftweed are rare in a review of the world position. To most workers the harvesting of the weed was a problem of a major order and its collection has been, as Robertson (1930) states, "no job for water-front loafers, but requiring hale, hardy and

thoroughly industrious men " and women, who knew the sea.

The degree of urgency, the availability of material and other factors have dictated the extent to which the scientific investigation of the autecology of the plants, including observations on their seasonal variation, could be carried out in different countries. Here again, however, the problems which the scientists faced had much in common, especially where the supply of the raw material was restricted and had to be used to the best advantage. The best season for harvesting had to be determined having regard to the growth and sporing periods of the plants. In addition, the correlation between growth, sporing and the gel strength of the extract had to be ascertained. Immediate decisions had to be made regarding methods of collecting that would not seriously destroy the communities and so affect subsequent harvests. Methods of manufacture had to be devised which were suitable for the particular weed that was available. The solution or partial solution of these problems has resulted in the production of agars of various types in many countries, some of which had never before attempted manufacture from local weed. Economic conditions and individual enthusiasm for harvesting and manufacture must govern the future, but in some countries where high-grade agar has been produced, commercial enterprise may well keep the established factories in permanent production. If this is to be so, there is clearly much more to be done in the investigation of the life-history and physiology of the weeds concerned. An attempt will be made to outline the position in various countries.

The properties of some of the agars from countries other than Japan are shown in Table 20, p. 90.

UNITED STATES OF AMERICA

In America, the position has been reviewed by Tseng (1944 a,b,c, ; 1945a). He points out that agar is the only seaweed product that received the attention of the American War Production Board. The commodity was 'frozen' commercially two months after the Pearl Harbour attack, and its use restricted to the preparation of bacterial culture media. The annual importation from Japan had varied between 497,000 and 704,000 lbs. between 1937 and 1941.

The first agar factory in the Western hemisphere was opened at Glendale, California, in 1920 by a Japanese, Chokichi Matsuoka (Tseng, 1944c). He used Japanese methods, but introduced artificial freezing and chlorine bleaching. There appears to be some doubt about the type of weed he used. He secured patents emphasizing the use of *Gloiopeltis*, but there is more probability that his raw material was actually *Gelidium cartilagineum*. The business was not successful financially and later it was sold to a group of Americans. Subsequently, John Becker modified the method and took out patents covering a special combined congealer and sizer, a de-waterer for flaked agar, a dehydrator, and also a

patent covering his entire process of manufacture (Tseng, 1945a). Becker's process was still in use in 1945, although the company with which he worked could not stand the strain of trade depression and closed in 1933. A former employee opened a small factory in National City, California, which worked under the name of the U.S. Agar Co. The agar it produced was largely reprocessed from the Japanese product, but the company became the nucleus of the American Agar and Chemical Co. in San Diego which was producing about 87% of the total agar made in the U.S.A. during the 'freezing' order referred to above. In addition to this large concern, other factories have been set up at Los Angeles, Orange and Whittier. The weed used is mainly *Gelidium cartilagineum*, which is harvested from Point Concepcion southward on the Californian coast, and also in Mexico. It occurs from low tide-mark down to 30 feet or deeper in turbulent waters. It attains a length of 4 feet or more but is harvestable when 18 inches long. Large quantities are obtained by diving, though some is collected by means of long-handled rakes. In six diving hours, an experienced diver is said to gather as much as one ton of wet weed (Tseng, 1944c). The task, however, is precarious, and the work is entirely dependent on calm seas. Previous mapping is not practicable, so the divers have to search for good areas by crawling along the rocks, using large brown seaweeds for support. They pick the weed into baskets which, when full, are pulled to the surface by the boat's crew. Divers can work from May to November in water 15 to 30 feet deep, if there is no ground swell and the sea is relatively calm. No practical mechanical harvester has been found, though much time and money have been spent in an endeavour to devise one. The difficulty, which is common to workers in almost all marine algal fields, is the discontinuous distribution of the weed, the habitat of which is usually below the tide-marks on jagged rock ledges. This makes the cost of seaweed raw material very high, unless exceedingly cheap labour is available.

After collecting, the weed is sun-dried and baled, but not bleached. It is processed by obtaining a series of hot extracts in pressure cookers. The hot solution passes through filter tubs and gels on cooling, the resulting gel being crushed and poured down into cans in the freezing room, where it remains for two days at 14°F. After the gel has thawed, the water and impurities are separated in rotary vacuum filters and the resulting flakes, which still carry a high percentage of water, are dried in stack driers by ascending hot air, until they are dehydrated to about 35% moisture content. They are then bleached in 1% sodium hypochlorite at room temperature and the excess hypochlorite reduced by a solution of sodium sulphite; the flakes are then washed and dehydrated to about 20% moisture. Tseng (1944c) suggests that the method might be further improved and a way sought of reducing the loss in the discarded pulp after extraction. He also suggests (*loc.*

cit.) that there should be further research on the biology of the *Gelidium* and that the possibility of using other weeds, such as *Gracilaria confervoides*, might be explored further.

The increased demand during the war years has stimulated a manufacturing industry in Mexico, and Humm (1942) records that in Beaufort, North Carolina, *Gracilaria confervoides* is being used for the manufacture of an agar which, though perhaps not of the grade for bacteriological use, might nevertheless help to meet other needs. Companies producing agar are also said to have been started in Massachusetts and New York State. Even if the agar from *Gracilaria* is not of such high grade as that from *Gelidium*, it might still be of commercial value partly because the initial cost of the raw material is likely to be lower. *Gracilaria* tends to occur in sheltered bays near river estuaries, often on sand-covered rocks. The water is shallow, the movement frequently sluggish and the bottom much less rugged than habitats that favour the growth of *Gelidium*. Harvesting of *Gracilaria* is therefore much easier than it is in the case of *Gelidium*. One man is said to be able to rake a ton of wet *Gracilaria* during one period of low tide; it takes seven tons of wet weed to yield one ton of dry. Further research is recorded by Humm (1944), and in a recent series of papers by Humm *et al.* (1946) much further progress is recorded in the ecological study and utilisation of *Gracilaria confervoides*. It is also stated that *Hypnea musciformis* is a possible agar-weed.

Research on problems connected with agar manufacture and the plants concerned is in progress at the Scripps Institute of Oceanography, La Jolla, San Diego, and the Technological Laboratories of the U.S. Fish and Wildlife Service, as well as at the Duke Marine Laboratory, Beaufort, N.C.

CANADA

Chondrus crispus is harvested for commercial use in the food industry (Fulton and Metcalfe, 1945). Some work on agar-producing seaweeds has been recorded (Anon., 1946), especially on *Gracilaria sp.* at Vancouver. An attempt is also being made to use *Halosaccion*.

NEW ZEALAND

In New Zealand, agar research has been under the direction of L. B. Moore (1941, 1944) in the Plant Research Bureau of the Department of Scientific and Industrial Research, at Wellington, in North Island. In 1939 over 23,000 lbs. of agar were imported (Moore, 1944) and an early attempt was made to study the available raw material and produce a bacteriological agar. Great success has attended the investigation of two species of *Pterocladia* (*P. lucida* and *P. capillacea*), both of which occur in commercial quantity on the rocky exposed coasts of North Island and on the north-east corner of South Island. It has been established that satisfactory regeneration occurs after harvesting

and that an annual collection can probably be made without damage to future crops. Observations have been made on the reproductive phases of the plants, and due regard has been given to the maintenance of the crop by sexual reproduction, by the production of tetraspores and by vegetative regeneration. Unlike the majority of red algae, the plants produce throughout the year both sexual and tetrasporic reproductive bodies, though the amount of fertile material varies considerably. Much of the collecting has been done by Maoris, and the New Zealand scientists, like those in Britain, have obviously had to face the difficulties of teaching lay-workers to collect a quantity of material that "presents a puzzling variety of forms" (Moore, *loc. cit.*). Dry weed has been purchased for 1/- per lb. by the Internal Marketing Division which operates under licence from the Bureau of Industry. The material was re-sold to a manufacturing firm. *P. lucida*, which is larger than *P. capillacea*, and reaches a maximum length of about 2 ft., has constituted the bulk of the material used, and agar made from it is satisfactory both for bacteriology and for meat-canning. About 60 tons of dry weed were purchased during the first year of operations, and in 1944 it was still being harvested at a satisfactory rate. *Pterocladia* agar has a good colour and high gel strength.

Collecting appears to have been done by combing the drift, by picking from the rocks, or by diving in about 6 feet of water. Diving is the practice normally used by the Maoris for catching crayfish. Off-shore reefs have been reached by swimming out a horse and rider, and another successful method was to walk beside a boat, waist to armpit deep in water and feel for the weed with the feet. Bags into which the gathered weed could be placed by hand, after being located with the feet, were dragged behind the worker and emptied periodically into the boat. One harvest from a boat in one day yielded as much as 200 lbs. dry weight.

After gathering, the weed was washed in fresh water, dried in the sun, and then cleaned. Much trouble was occasioned by the epiphytic coralline algae that grow so profusely on *P. lucida*, and the best method of removing them from the dry weed was to beat the material with a flail. Weed heavily infested with *Polyzoa* and sponge incrustations had to be discarded. Examination of data indicates that the peak harvesting periods occurred in May and June in 1943. Manufacture was taken up by a firm whose main products are gelatine and glue. Extraction was carried out under pressure, in several changes of water, the extracted liquor being drawn off, bleached and filtered. The filtrate was cooled and set in enamelled pans, the gel cut up and dialysed, and the majority of the non-gelling compounds removed by freezing. After thawing, the contracted gel was dried by hot air, until the moisture content was below 18% (B.P. requirement). The dry agar was then ground to a fine powder which was sifted and blended into a standard product. The yield has shown considerable

variation, mainly through irregularities in the condition of the weed. Actually, harvesting appears to have taken place to some extent throughout the year, a fact which might easily affect the gel strength if *Pterocladia* has peak periods for its main reproductive phases which can be correlated with gel strength, as has been found for *Gigartina* in Britain.

Tests carried out at the Dominion Laboratory show that *P. lucida* gives an agar of which the colour and clarity of sol are at least equal to the best Japanese (Moore, *loc. cit.*). The melting point is high (86.5°-89° C.) and the setting point varies from 35°-39° C. An experimental sample was analysed at the Imperial Institute, South Kensington, London,* and gave the following approximate result:

	% of original material
Moisture.....	13.2
Cold water soluble	4.5
Hot water soluble.....	85.3
Ash	3.5
Protein	1.1

Agar from *P. capillacea* presents more difficulty in manufacture than that from *P. lucida*, though the gel strength is similar. Experimental agars from *Gelidium caulacanthum* and *Gracilaria confervoides* have also been made, but by far the best results appear to have been obtained from *Pterocladia lucida*. *P. lucida* and *P. capillacea* agars are suitable for meat canning and commercial purposes as well as for bacteriology.

AUSTRALIA

In 1941 it was reported that Australia would be able to meet its own essential medical requirements of agar by the utilisation of large quantities of *Gracilaria confervoides* from estuaries on the south-east coast and from the Swan River in Western Australia (Anon., 1941 a,b). A large tonnage of the weed was washed up close to Sydney and it was thought probable that there were other localities where a similar phenomenon might be expected. In any event, bulk harvesting from sandy estuaries is much easier than rock collecting, and in addition a mechanical harvester could be used (Wood, 1941). Australia was thus singularly fortunate in her initial endeavour and the ease with which her raw material can be obtained may make her eventually a competitor in the world market (Wood, 1942). In any event, it enables her to prepare an agar for her own peace-time canning and confectionery needs as well as for medical purposes. The *Gracilaria* agar was examined at the Imperial Institute, London, in 1945, and reported to be satisfactory for pharmaceutical use and very similar to Japanese commercial agars.

After collecting, the weed is cleaned of sand by shaking or washing, dried, and sun-bleached. It is

then baled for storage. Manufacture consists of extraction with water at 230° to 240° F., decolorising with charcoal, and filtering, using filter-cel or an Australian equivalent. After being allowed to set, it is cut into ½ in. strips and frozen overnight, being subsequently thawed and dried in the sun or in a drying tunnel.

It was suggested (Anon., 1941a) that much remained to be done in the study of *Gracilaria* to ensure continuity of supply; attempts were also being made to improve the product still further. More recently the position has been reviewed by Wood (1945) and it is evident that much progress is being made.

SOUTH AFRICA

South African workers have used *Gelidium cartilagineum*, *Gracilaria confervoides*, and *Suhria vittata*, with marked success. Other seaweeds have been found suitable for agars of lower grade, but the most profitable source is probably *Gracilaria* (Isaac *et al.*, 1943). Here again, the ease of obtaining *Gracilaria* as compared with other weeds is probably one important factor. *Gracilaria* is recorded by Isaac (1937) as occurring in considerable quantity around Langebaan and in Hout Bay (Isaac, 1942). It is also recorded as occurring in great quantity at times in the drift weed. The culture of weed for agar manufacture appears to be contemplated and there is likely to be legislation for the conservation of *Gelidium corneum* which occurs in quantity on certain coasts (Anon., 1945).

INDIA

When war broke out, there appears to have been little, if any, reserve agar in India, though a small amount was available in bazaars for domestic use. An Indian substitute, known locally as China-grass and made from Ceylon moss (*Gracilaria lichenoides*) was also on the market. It was essential that a medium for the growth of cholera and typhoid vaccines should be available, twelve million doses a year being produced by one laboratory alone.† Experiments on agar were carried out in Madras, using *Gracilaria lichenoides* as a source of material. The samples varied in quality but the agar was used successfully for the emergency preparation of vaccines. That the preparation of a bacteriological agar from *G. lichenoides* is possible, is borne out by tests carried out at the Imperial Institute, London, on agar made in Malaya from weed imported from India. *Gracilaria confervoides* was also used successfully (Bal *et al.*, 1946) during the war years.

MALAYA

Experimental work in Malaya included the use of *Gracilaria lichenoides* from the Netherlands East Indies, as well as from the Malayan shores. A report from the Imperial Institute, London, states that the samples submitted showed that this weed might be a promising possible source of bacteriological agar.

*These and other figures have been kindly supplied by the Imperial Institute.

†Information from Major-General J. Taylor, I.M.S. Director.

In Java and Macassar a small quantity of agar was made from *Eucheuma denticulatum*.

CEYLON

In Ceylon, agar was made from *Gracilaria lichenoides* and *Gracilaria confervoides*, gathered at the time of the south-west monsoons. Ceylon agar is said to contain only 37% gelose as compared with 60% in the Japanese product.

EIRE

The west coast of Ireland has been an important source of carrageen for many years and considerable research on the ecology of the plants concerned and their commercial harvesting has taken place, though they have not been used for the manufacture of agar. The term 'carrageen' is used to mean either *Chondrus crispus* (L.) Stackh. or *Gigartina stellata* Batt., or a mixture of both these weeds. Recent work has led to the conclusion that *Gelidium pulchellum* and *Gelidium latifolium* are suitable plants for the making of a satisfactory agar and that they occur in sufficient quantity on the Irish coasts to make the project profitable. It was stated (Anon., 1942-1943) that production of agar on a limited scale by one commercial firm would begin in 1944, following the location of the relevant weeds in harvestable quantity on the coasts of Galway, Clare, Kerry and Cork. More recent information suggests that the venture was not a commercial success.

FRANCE

Sauvageau (1920 a,b), an eminent French algologist, has written of the possibility of producing an "agar-like substance" from various seaweeds which occur on the coast of France, but no extensive industry of that kind appears to have been developed, though France, like other European countries, imported Japanese agar before the recent war. The harvesting of *Chondrus crispus* is an important industry on parts of the French coast, though no record of its use as a source of agar has been found.

RUSSIA

Before the war, Russia was an importer of large quantities of agar, and the literature shows that considerable research had taken place in an attempt to produce agar from seaweeds known to occur in coastal waters (Gryuner, 1931; Kizevetter, 1937 a,b). According to Kizevetter (1937 a), Vladivostok and Archangel each produced 44,000 lbs., and Vladimir 33,000 lbs. in 1936. This was made from *Ahnfeltia plicata* by extracting with lime. An agaroid has been made by using *Phyllophora rubens* from the Black Sea (Elin *et al.*, 1931). The process is not wholly disclosed, but a preliminary bleaching with 0.16% H_2SO_3 appears to have effected partial hydrolysis and to have accelerated swelling and diffusion (Korentzvit, 1934). It is said that 20%-25% of agaroid was extracted from the dried weed. The melting point was from 90° F.

92° F. and the agaroid made a satisfactory gel in a 6% solution. This is, of course, a much stronger solution than is normally necessary for bacteriological work, using a true agar. Odessa, on the Black Sea, was reported to have produced 440,000 lbs. of agaroid in 1936. Comparative physico-chemical studies of agars of different origins have been made. The agaroid described above has been compared with *Ahnfeltia* agar of Japanese and Russian maritime coasts and of the White Sea. It was found that the maritime grade ranked highest in technological application (Kizevetter, 1937 b).

CHINA

Up to 1937, China had a small agar industry at Ningpo, Tsingtao and Chefoo with an estimated production of about 75,000 lbs. (Tseng, 1944a). From information obtained through the British Council,* it has been ascertained that during the war a new process was tried out on a factory scale in 1943, and reported at the annual meeting of the Chinese Medical Association at Chungking in May, 1944. Species of *Gelidium* were collected, cleaned and sun-bleached, extracted with hot water, and the extract filtered and allowed to set. After cutting up, the water was removed by solar heat, or air drying. For this latter part of the process the agar strips were spread on dry cotton cloth over bamboo matting, the cotton cloth absorbing the water from the jelly. It is claimed that the method is an economy of capital and of time, as well as enabling the agar to be made readily on the shore where the weed is harvested. It is also claimed that the jelly content is higher in the resulting product. Humm *et al.* (1946), however, say that drying without freezing does not make such a good agar because it is tough and difficult to dissolve. The Chinese agar was tested and found suitable by the Serum and Vaccine Institute of the Army Medical College at AnChen, and by the Vaccine Plant at Kweiyang. Unfortunately, no extensive manufacture was possible, because the area was cut off by the Japanese advance in 1944.

GERMANY

Enquiries in Germany by the Ministry of Health† since the cessation of hostilities, have revealed that the need for agar in that country was met by large pre-war stocks and also by the use of recovery methods. It was reported from one laboratory in Berlin that agar had been obtained from Japan by submarine. Black Sea sources do not appear to have been used when Germany had access to parts of that coast, according to the evidence of bacteriological workers who had served in the Crimea and Caucasia. Recovery methods were reported to be in process in most laboratories.

PORTUGAL

A small sample of agar which was received in Britain from Portugal during the war had the characteristics of a *Gelidium* agar.

*Information through the kindness of Dr. D. M. Needham. †Through Dr. W. P. Kennedy.

SPAIN

Gelidium corneum has been used for making agar and the harvesting of this weed and of *Chondrus crispus* has been controlled.*

ITALY

Some *Gracilaria* from the lagoons in the neighbourhood of Venice was used during the war for the manufacture of agar (L. C. Beadle, personal communication).

BRITAIN

In Britain, the problem of the agar supply was recognised early in the war. Although a certain amount had been stored by the Government, it was necessary to investigate the possibilities of a local supply. Preliminary investigations by chemists and algologists led to the conclusion that of the available red seaweeds, *Gigartina stellata* Batt., *Chondrus crispus* (L.) Stackh., *Ahmfeltia plicata* Fries, *Gracilaria* sp. and *Gelidium corneum* Lamour, were probably the most suitable for investigation. V. J. Chapman in 1942 collected some preliminary data on the occurrence and distribution of the red seaweeds already mentioned, while making a survey of the large brown weeds. Subsequently, the present authors selected *Gigartina stellata* Batt. and *Chondrus crispus* (L.) Stackh. for further work, though neither species had previously been regarded as an agar producing weed. They were known from our earlier studies to occur abundantly around British coasts and the possibility of utilising them as a source of agar had been ascertained by A. P. Orr and S. M. Marshall.

The two algae *Chondrus crispus* and *Gigartina stellata*, known collectively as carrageen, were collected regularly before 1939 in many places, including France, Canada, Eire, Northern Ireland, and the Western Isles of Scotland. They inhabit rocky shores near low tide mark and are highly esteemed by the coastal peoples, who harvested them regularly before the war. They were used largely in medicine and commerce as a gelatinous colloid, and in the Hebrides and Eire they were used for making milk jellies and as a palliative in the treatment of digestive complaints. Their curative properties were recognised by pigkeepers in Pembrokeshire and, in Anglesey, during the recent war, the coats of red setters suffering from restricted diet were found to be much improved by the addition of boiled carrageen—which the dogs ate greedily—to their meagre rations.

Detailed surveys of suitable localities in Britain from which to harvest large quantities of *Chondrus* and *Gigartina* were carried out. These areas were the coasts of Northumberland and N.E. England, S.E. Scotland, West Scotland and the Western Isles, Wales, Devon and Cornwall (Map 1). The main focus of the work was concentrated therefore on the west coast of Britain, though some harvesting has also taken place in a restricted area of Northumberland. These surveys will

be discussed later. Owing to transport difficulties Northern Ireland was excluded, though both *Gigartina* and *Chondrus* are known to occur there.

Having ascertained the distribution of these red seaweeds, the problem of harvesting had to be considered. It was evident that the latter would have to be carried out by people with no specialised knowledge of the plants, and a number of difficulties arose immediately. The first main problem was the polymorphism of the species concerned (see Colour Plates I and II, pp. 179 and 180). Secondly, the time of harvesting had to be determined, as it was necessary to ensure that the crop was gathered with due regard to the growth of the plants, as well as to their reproduction and regeneration. Thirdly, the gel-strength of the resulting agar had to be correlated with these findings. It was evident that a solution of such urgent harvesting problems could be obtained only by a study of the autecology of the plants themselves.

Primarily, the harvesters in any area had to be taught to distinguish the two species from other seaweeds. The extreme polymorphism of both plants rendered necessary the compilation of an herbarium and the circulation of sample sheets to illustrate the diversity of form of plants growing in different localities and under differing environmental conditions. Fortunately it was not necessary for the harvesters to separate *Chondrus* from *Gigartina*. The months when the crop should be picked had to be determined, and also the method of gathering which would be least deleterious to the next season's growth. Investigations were also made to ascertain whether it would be possible to increase the amount of *Gigartina* present in any locality by removing all plant competitors in the community, and at what rate *Gigartina* would colonise cleared rock surfaces within its own intertidal range.

In order to obtain information on these points, a study was made of the morphological types of *Gigartina stellata* and of the ecological factors which appear to govern their distribution. In addition, the anatomy and life-history of the species were investigated in a preliminary way, and records kept of the times of the vegetative growth periods, the fruiting periods, and the shedding of the spores. Preliminary attempts were made to grow the spores. Further investigations on the ecology, life-history and cytology of the plant are still in progress.

In practice the proportion of *Chondrus* harvested was very small, never more than 5% of the total harvest in any one year. After this had been ascertained, the greater part of the field investigations were carried out on *Gigartina*, the life-history of which was incompletely known.

A record of the surveys, an account of the botanical work which has been carried out on *Gigartina* and *Chondrus* and a description of the chemical investigations on agar production, follow in the succeeding chapters.

*This information has been received since the major part of this paper was written.

INVESTIGATIONS IN BRITAIN

I. SURVEY

IN 1941 preliminary surveys of areas in Scotland, Wales and south-west England were commenced. By the summer of 1942, it was evident that the greatest harvest would be available in the west of Scotland and subsequently quantitative surveys were concentrated in that region.

A list of surveyors is given in Appendix II, p. 103 *et seq.*

The work was very strenuous owing to difficulties of transport, including the frequent absence of roads to the shore, and the short daily exposure of the seaweeds concerned. In addition, the weeds usually grew on rocky shores where speedy movement was impossible and mechanical transport, even by boat, often impracticable. Much of the north-western survey was carried out in closed military areas, but the inhabitants of all the districts surveyed shared the common problems which inevitably beset coast-dwellers in wartime.

The month in which the survey of an area was made materially influenced the total estimates, as may be seen from the graphs in Text-figs. 19-26. Also, ideally, all surveys should have been made at extreme low water of spring tides, but here again, by wading or by observation from boats, approximate estimates had to be arrived at when tidal conditions were less favourable. In general it was found that in most areas the work could be carried out for two hours each side of the time of low water during spring tides, though the available time was shorter in some localities, as for example in N. Devon. The available time decreased as neap tides approached and then the possibility of doing any surveying at all was dependent on the suitability of the coast and the prevailing weather conditions. The time of day of low water at spring tides was a matter of great importance, not only for surveying but also for subsequent harvesting.

In making the first survey of England and Wales, attempts were made only to estimate visually whether or not an area was harvestable, having regard to the quantity of weed available, its accessibility and the nearness of the area to roads and human habitation. Any quantitative estimates were only approximate and were based on quantity per square yard within the zone.

In Scotland, at first, estimates of available quantities were made in the following way. In very rich areas the amount of *Chondrus* and/or *Gigartina* occurring on one square yard of shore was gathered and weighed in a net by means of a spring balance. Then the

total amount was calculated for an appropriate measured area within which the weed was similarly distributed. In regions which were less good, the rocks were cleared of the two seaweeds until one pound had been collected; the area so cleared was then measured and an estimate made of the amount available over a wider and comparable area. Both weighing processes could be eliminated when the surveyors had sufficient experience. In the early surveys, *Chondrus* and *Gigartina* were estimated together. Later, when possible, estimates of *Chondrus* were made separately from those of *Gigartina* but, if the two algae occurred in close association, an approximate visual estimation of the percentage occurrence of the two genera was made. More detailed surveys were necessary in areas such as the Isle of Cumbrae (Scotland) and the Gower Peninsula and Cardigan Bay (Wales), which were used for research.

When it was established that the maximum amount of *Chondrus* and *Gigartina*, especially the latter, occurred around the islands of western Scotland and large harvestable quantities were being estimated, it was found to be most advantageous to record the amounts available per linear yard of shore. All of the *detailed* Scottish records will be found to be uniform in this respect, with the exception of southern Ayrshire and Wigtownshire which were surveyed earlier (see also p. 19). *Gigartina* was far more abundant than *Chondrus* in the west of Scotland and very little *Chondrus* has in fact been harvested there. All estimates recorded on the appended maps and tables are given as wet weight. The correlation between wet and dry weights is given on p. 60 *et seq.*

Map I shows the areas which were surveyed; the collected details of the surveys are shown separately in the tables in Appendix III, p. 106 *et seq.* The notes in the tables provide an important ecological record from which much information on the significant ecological factors has been deduced. The maps showing the aggregate available weed have been given only where the yield was considered large enough to justify their inclusion. In other cases, the Ordnance map reference is given and the data should be read in conjunction with such a map. In practice, in the rich areas, more detailed maps were prepared* but the data on these have been summarised in the maps given here.

ENGLAND AND WALES

Parts of the coast, which were considered to be

*These detailed maps are held in the Directorate of Chemical Research and Development, Shell Mex House, London.

worthy of investigation from a harvesting view-point, were visited. When good areas were found, local labour was organised for harvesting. The following notes indicate the localities visited; the numbers in brackets following the letters O.S. refer in each case to the New Series of the 1 inch Ordnance Survey sheets. The harvesting of the weed will be dealt with in a later chapter.

SCOTLAND

Much of the west coast of Scotland and the Western Isles was surveyed and mapped; local labour was organised for commercial harvesting. Relatively little carrageen occurred on the east coast and military operations hindered harvesting. References are given for appended tables and maps for most areas regarded as harvestable.

ENGLAND

SOUTH DEVON

PORTLAND BILL TO BERRY HEAD

(1) *Beer* (O.S. 139)

Small isolated collecting area north of cove, on Middle Chalk and Beer freestone, and also southwards towards Beer Head. Steep shore with narrow algal zone, *Gigartina* fringing pools and flanking boulders, occurring also under *Fucus serratus* at lower levels.

(2) *Bull Island in mouth of Exe* (O.S. 138)

About 500 lbs. of *Gigartina* present; not harvestable during the war owing to danger of machine-gunning by low-flying enemy planes.

(3) *Dawlish* (O.S. 145)

Harvestable area on Permian rocks from Dawlish breakwater westwards towards Teignmouth, restricted only by headlands. *Gigartina* present but not in large quantity; easy to harvest from flat boulders in the mid-tidal zone and from rocks at lower levels; *Laurencia* present with the *Gigartina*.

(4) *Paignton area* (O.S. 145)

Meadfoot Bay not harvestable, though outcrops of Meadfoot Beds further west carried good crops of *Gigartina*; a little *Chondrus* present in the upper pools. Hollecombe rocks at Preston carried a good harvestable crop of *Gigartina*.

BERRY HEAD TO THE MOUTH OF THE DART
(O.S. 145)

The coast is high and rugged; rocky areas are inaccessible.

Dartmouth area

Steeply tilted 'Dartmouth Beds' were surveyed by

boat from the Mewstone to Pilchard Cove. A considerable crop of *Gigartina* was present, but was heavily infested with mussels. Similar settlements have been observed in Scotland where they are known to be sporadic. In neither case does the growth of the *Gigartina* appear to have been permanently impaired.

START POINT TO BOLT TAIL (O.S. 145)

This area includes the four large headlands Start Point, Prawle Point, Bolt Head and Bolt Tail. Wherever access to the intertidal region was possible, considerable quantities of *Gigartina* were recorded and were observed to be abundant on certain mica or hornblende schists and absent on others. For practical purposes, only the area from Prawle Point to Lannacombe Bay was harvestable.

BOLT TAIL TO BURGH ISLAND (O.S. 145)

Hope Cove on the Staddon Grits and Thurlestone rocks on the Meadfoot Beds yielded a considerable harvest of *Gigartina*.

BURGH ISLAND TO PLYMOUTH (O.S. 144)

In Wembury Bay the flanks of the rocks from mid-tide to low water of springs carried a harvestable crop of *Gigartina*, from the *Fucus serratus* zone down to the *Laminaria* zone. At Bovisand Bay and Jennycliffe Bay, in the more sheltered waters of the Sound, the *Gigartina* extended above the *F. serratus* and into the *Ascophyllum nodosum* zone. Such an upward extension of the *Gigartina* zone has been observed elsewhere in sheltered bays. Contamination by oil ruined parts of these crops in successive years.

NORTH DEVON

In this area the *Gigartina* appears to be exposed for a shorter period than in South Devon. This may be due to a difference of relative position, a difference of tide or some other cause, but it is a striking feature and one

of considerable importance for harvesting.

HARTLAND QUAY (O.S. 127)

A good quantity of harvestable weed was available in and around this area.

HARTLAND POINT TO BARNSTAPLE
(O.S. 127, 118)

The only harvestable area is that of the Carboniferous rocks of the Upper Culm measures from Cockington Head towards Westward Ho. *Chondrus* was present in the upper part of the mid-tidal area and *Gigartina* at lower levels. The plants were much mixed with other algae and harvesting was difficult from that point of view.

CROYDE BAY TO HANGMAN POINT
(O.S. 118)

Chondrus and *Gigartina* were harvestable in six localities within this area.

(1) *Flanks of Croyde Bay*

Harvestable chiefly at Baggy Point.

(2) *Morte Point and Rockham Bay*

Long rock ridges separated by gulleys carried crops.

(3) *Lee Bay*

Chondrus occurred in the pools and *Gigartina* was present in harvestable quantity among the *Fucus serratus* and at lower levels.

(4) *Tunnels beach, Ilfracombe*

Flattish rock-pools from mid-tide level downwards and lower rocks provided harvestable *Chondrus* and *Gigartina* respectively.

(5) *Hele Bay*

Harvestable *Gigartina* on rocks flanking Beacon Point.

(6) *Combe Martin Bay*

Abundant *Gigartina* from the lower part of the *Fucus serratus* zone, downwards into the *Laminaria* zone.

SOUTH CORNWALL

RAME HEAD TO GRIBBIN HEAD

(1) *Looe* (O.S. 144)

Neither *Chondrus* nor *Gigartina* was present in harvestable quantity.

(2) *Talland rocks* (O.S. 144)

Composed of Lower Devonian Dartmouth Beds, these rocks provided a harvestable crop of *Gigartina*, which occurred on flat-topped boulders and continued into the *Ascophyllum nodosum* zone where it thinned out rapidly.

(3) *Coombe Cove, Fowey* (O.S. 143)

The Lower Devonian rocks were similar to those exposed at Thurlestone and bore a similar marine flora. *Gigartina* was prolific and harvestable from the *Laminaria* zone through the *F. serratus* to the base of the *A. nodosum* zone.

(4) *Polridmouth* (O.S. 143)

Harvestable *Gigartina* occurred especially among *F. serratus* and *Himanthalia lorea* and extended upwards, where shelter was available, into the *Fucus vesiculosus* and *A. nodosum* zones.

GRIBBIN HEAD TO PENARE POINT
(O.S. 143)

(1) *Par harbour*

The spit and adjoining beaches carried heavy crops but for military reasons were available only late in the war.

(2) *Portmellon*

Geologically the rocks are Mylor Sands and Grams-

catho Beds. *Gigartina* occurs abundantly, especially on the southern side of the bay under *F. serratus*.

(3) *Colona beach*

The rocks are geologically similar to those at Port Mellon and bore a prolific crop of *Gigartina* among *F. serratus* and *F. vesiculosus*.

(4) *Vault beach*

The rocks to the north of the bay are lavas with Dodman Phyllites to the south. All the rocks bore rich *Gigartina*, mostly among the Fuci at lower tide levels and mixed with a little *Chondrus* in the upper reaches. A broad frilled form of *Gigartina* occurred on these rocks.

(5) *Hemmick beach*

This beach had 40% *Chondrus*, 60% *Gigartina*, a higher proportion of *Chondrus* than any beach westward from Beer. The total amount of these weeds was less than that occurring in the bays to the east of Dodman Point. *Himanthalia* was one of the associated weeds, together with *Nemalion* and *Ptilota*.

(6) *Port Holland and Porthluney*

The rocks are geologically similar to those at Port Mellon and yielded harvestable crops of *Gigartina*.

PENARE POINT TO ROSE MULLION HEAD
(O.S. 143, 146)

(1) *Falmouth area* (O.S. 146)

Geologically the area is in the Falmouth series of argillaceous and fine sand beds with interbedded slates. Three areas yielded good harvestable quantities of *Chondrus* and *Gigartina*.

(2) *Gyllyndune shore and Swanpool rocks* (O.S. 146)

Between Pendennis Point and Penance Point.

This more or less self-contained area provided an interesting comparison with most of the other collecting grounds on the south coast, in that, as at Swanage and parts of Studland Bay, meadows of almost pure *Chondrus* occurred.

(3) *High Cliff, south of Maen Porth* (O.S. 146)

Harvestable area of *Chondrus* and *Gigartina*.

(4) *Hutches rocks* (O.S. 146)

Harvestable area of *Gigartina*.

ROSE MULLION HEAD TO LAND'S END
(O.S. 146)

Coverack Cove north of Dolor Point, Porthleven and Prussia Cove east of Cudden Point, all carried crops but were inaccessible.

Marazion rocks, St. Michael's Mount

Mylor and Portscatho Beds extend into Mounts Bay with masses of epidiorite. Rocks to the east of the causeway and those surrounding the bay towards Little London carried a prolific crop of *Gigartina* which was easily harvestable from flat-topped rocks.

NORTH CORNWALL

LAND'S END TO BUDE HAVEN
(O.S. 143, 146, 136)

A long range of precipitous storm-beaten shores, the flanking rocks of which provided a substrate for some *Gigartina* and a little *Chondrus*, but nowhere on such a prolific scale as in South Cornwall. Three harvestable areas occurred.

(1) *Newquay* (O.S. 143)

Chondrus and *Gigartina* were present on the slates of the Meadfoot Beds, including the rocks flanking Fistral Bay.

(2) *Treyarnon beach* (O.S. 136)

South of Constantine Bay and Trevoze Head at the junction of the Upper and Middle Devonian Beds, a

small amount of *Chondrus* and *Gigartina* occurred, the plants being short and light in colour.

(3) *Dayner beach near Trebetherick, and rocks abutting on the Greenaway at Polzeath* (O.S. 136)

Both areas were on Upper Devonian Beds and yielded harvestable *Chondrus* and *Gigartina*.

BUDE AREA (O.S. 136)

Upper Devonian rocks are succeeded near Boscastle by Carboniferous strata which extend as far north as Barnstaple.

Gigartina with a little *Chondrus* occurred on various beaches but most of the cliffs dipped too steeply for harvesting. Accessible areas occurred, however, on the shore platform which sloped gently seaward to the south of Widemouth Bay and Bude.

DORSET

SWANAGE AREA (O.S. 141)

The fact that a considerable meadow of *Chondrus* existed at Studland Bay was known, but military

operations prevented the area being harvested. A good yield of *Chondrus* was present, however, on the rocks to the west of Swanage Bay and east of Peveril Point.

NORTHUMBERLAND (O.S. 2, 4)

No detailed survey of this coast was undertaken, but in view of information received on the prevalence of *Gigartina* and *Chondrus* a harvest was taken. The

best localities were reported to be Newbiggin, Cresswell, Boulmer and Beadnell. This was the only east coast locality from which carrageen was harvested.

WALES

Various parts of the coast were visited, particularly where likely areas for harvesting were known to exist. Both *Chondrus* and *Gigartina* occurred in harvestable quantity in parts of the Gower Peninsula and in Cardigan Bay, but in view of the fact that these areas were needed for research work, no attempt was made to take a harvest

after 1943, nor are the very detailed surveys which were made included in the present work. The surveys in both cases were concerned with detailed distribution and from them areas were chosen for particular experiments. Of the remainder of Wales only the Anglesey coast proved harvestable.

ANGLESEY (O.S. 41)

The rocky shores of the north and west yielded both *Chondrus* and *Gigartina*. The more muddy coasts of the south-east were not harvestable though small quantities of both plants were present. On the north-eastern coast where sandy bays alternate with rocky headlands, the latter bore harvestable weed. The western coasts showed very clearly the way in which *Chondrus* flourishes on shingle higher up the shore than *Gigartina* in places where fresh water trickles into the sea. The presence of *Gigartina*, near the confluence of fresh water streams with the sea, was also observed on these stretches of coast.

LLEYN PENINSULA (O.S. 49)

A visit was made to this region, but though the seaweeds were present they proved to be unharvestable. In parts the coast was mined, in other places it was inaccessible, while in others there was neither village nor homestead within reach of the shore. Even where isolated houses occurred near the shore, the distance from a railway made harvesting impracticable.

PEMBROKESHIRE COAST (O.S. 88, 89)

No area which was accessible proved to be worth long term harvesting, but military occupation and land mines rendered the survey difficult or impossible in many parts.

SCOTLAND

BERWICK ON TWEED TO EDINBURGH (O.S. 68, 75)

The coast was known to be good for *Gigartina* but, owing to military occupation and mines, survey was difficult and harvesting impossible. It was ascertained that over eleven tons of weed were available from

Coldingham to North Berwick, all of which was *Gigartina* except south of Dunbar, where 10% of *Chondrus* was included from Seafeld Cottage to Lawrie's Den. The aggregate figures are given below.

TABLE 1
SHOWING QUANTITIES OF AVAILABLE GIGARTINA
AND CHONDRUS FROM COLDINGHAM TO NORTH
BERWICK

LOCALITY	ESTIMATED WET WEIGHT AVAILABLE, IN LBS.	NOTES
North Berwick	600	Poor in places
Seacliff	6,500	Scattered distribution
Dunbar	7,540	Good
Dunbar to Skateraw	5,280	Scattered
Torness Point	4,500	Some dense patches
Coldingham	1,600	

TOTAL : 26,020 lbs. = 11½ tons

EDINBURGH TO DUNCANSBY HEAD

The coasts near the Firth of Tay and Moray Firth carried crops, but they were not considered profitable

for detailed survey in comparison with the much richer areas elsewhere.

DUNCANSBY HEAD TO CAPE WRATH

Neither *Gigartina* nor *Chondrus* was present in harvestable quantity.

WESTERN SCOTLAND AND THE WESTERN ISLES

In view of the early discovery of the richness of the Clyde sea-area, attention was focused on Western Scotland and the Isles. The Firth of Lorne may be

taken as a convenient dividing line, and the areas north and south of it will be considered separately in the following account of the surveys.

NORTH OF THE FIRTH OF LORNE

The mainland from Cape Wrath to the northern shore of Loch Linnhe was not a harvestable area. The coast is fissured with fiord-like inlets which are either steep-sided or partly occupied by narrow valleys through which the rivers flow to the sea. In the first case, the topography does not encourage a rich growth of *Gigartina*, and in the second, *Ascophyllum Mackaii* Holm. & Batt. often forms a carpet at low tide in the partially silted lochs and neither *Chondrus* nor *Gigartina* is present. The small areas of coast between the lochs do not carry a sufficiently rich harvest for exploitation.

The islands off the coast, some of which proved very rich in *Gigartina*, may be divided into the inner and outer Hebridean chains. In these, two main geological series are represented (Harker, 1941). The first is Pre-Cambrian and is seen in the Outer Isles, as well as in Coll, Gunna, Tiree and Iona. It consists mainly of gneiss, a metamorphic rock, which is intersected by later intrusions also of Pre-Cambrian age. The second is formed of Tertiary rocks which are here the result of vigorous igneous activity. These latter rocks have formed extensive basalt tracts in Mull and Skye, where the hills are often terraced by lava flows. Jointing has often given rise to a honeycomb formation with columns perpendicular to the cooling surface. Tertiary sills have in places been forced into Jurassic beds. These features are well seen in coastal areas, have influenced

the form of the present coastline, and are therefore relevant in the present study.

Parts of some of the islands were covered with boulder-clay in a post-Tertiary glacial epoch. Following the ice-age, there was a general elevation of some of the land surfaces, as may be clearly seen by the raised beaches which are evident when soft evening lights silhouette the Treshnish Isles, the Dutchman's Cap, Linga and Fladda, and the old level appears at a uniform height above the surrounding waters.

Another conspicuous feature of the Outer Isles is the large areas of thin peat containing freshwater lochs, which are interspersed with marine inlets to such an extent that they are only distinguishable on the landward side by the nature of their marginal vegetation. The study of the coasts of such islands, with their varied geology, relatively mild climate, high winds, seas which may be either like sheets of opalescent turquoise glass, or mountainous with the force of the open Atlantic, provided good opportunity for observing some of the factors which determine the occurrence and the ecology of both *Gigartina* and *Chondrus*. During the survey, attempts were made to note correlations between the occurrence of the plants and the geological structure of the shore and its topography. In addition, the occupations of the human communities were observed, particularly in relation to their seasonal tasks and the facility with which harvesting might be arranged and the weed subsequently transported.

OUTER HEBRIDES, WITH COLL, GUNNA, TIREE AND IONA
(Pre-Cambrian series)

The Outer Isles, together with Coll and Tiree, were served during the years of the survey (1941-45) by passenger boat from Oban. Iona was reached by ferry from Fionphort, after crossing to Mull by boat and traversing that island by road. Gunna was reached by small boat from Tiree. Cargo boats from Glasgow called at the larger islands about once in ten days.

One of the striking features of most of these islands is the marked difference between their north-western and south-eastern shores. With the exception of Iona, the configuration of them all is narrow and elongated; the two main coasts being the north-west and the south-east. The north-western shore consists of sandy bays alternating with rocky headlands. The shore-line is backed by high blown dunes, behind which are areas with sandy soil, known as the 'machair,' which

either forms good pasture, or is cultivated. It appears to consist of wind-blown sand over peat, the blown sand having a high proportion of calcareous shell. The south-eastern coast-line of the Outer Isles and Coll is broken by lochs which are often very deep, with suddenly shelving shores. Tiree has not this marked contrast in the coastline of the two sides of the island, and the 'machair' covers a very considerable area. The extent of the 'machair' on the islands appears to control, very largely, the welfare of the inhabitants. The area which is not 'machair' is treeless, peaty moorland, interspersed with innumerable fresh water lochs. The moorland provides only sheep walk.

Under these circumstances, in a community that depends on farming and the products of the sea, where in most cases bread is delivered by cargo boat only once

in every ten days, the housewife is busy in her kitchen, and all available labour in summer is used either on the farms of the 'machair' or in lobster-catching, fishing, and the other related occupations of island dwellers.

The population is diminishing in any case and was still more depleted in war-time, so that the harvesting of carrageen even where it occurred in quantity, was clearly a very difficult proposition. It is possible, however, that with the return of peace-time conditions, a harvest might profitably be taken on Tiree, which has the richest yield of any of this group of islands. A major difficulty would be the drying of the crop, as it is unlikely that wet weed could be collected and transported to the mainland, especially in summer when occasional hot days would prohibit transport by passenger boat, and the uncertain timetable of cargo boats would introduce other problems. Detailed quantitative estimations have not been made on the islands of this group, but the following notes outline the conclusions.

SOUTH UIST (O.S. 23, 32)

Low water of spring tides occurs about noon G.M.T. The contrast between the north-western and south-eastern seaboard is very marked. On the south-eastern side steep cliffs and deep lochs occur, with shores that may show narrow zones of *Pelvetia canaliculata*, *Fucus spiralis*, *Ascophyllum nodosum* and *Fucus serratus*, before dropping suddenly into deep clear water in which immense fronds of the Laminarias and Himanthalia may be seen. Examination was possible only by boat but it was evident that Gigartina and Chondrus were usually absent or scarce. An intertidal zone of large boulders between the base of the *F. serratus* zone and the Laminarias, which is usually so favourable for the growth of carrageen, was not present on account of the steepness of the shore. Around the islands of Lochboisdale there was a little Gigartina, but it was not present in harvestable quantity.

The north-western side of the island is open to the full force of the Atlantic. Much of the coast is a silver strand of fine, highly calcareous sand. There is evidence of very considerable drift weed in the sandy bays and large plants of the Delesserias, Nitophyllum, Plocamium, Polysiphonia and Ceramium are washed up in quantity, as well as Laminarias. The sandy bays carry no algal growth, but the rocky headlands between them carry a rich flora. In these areas, where the coast drops gently to deep water or the littoral zone suddenly gives place to a great depth of water, Gigartina is present in varying quantity at the base of the *F. serratus* zone.

On the short southern coast of the island, Gigartina is present where the littoral zone is sufficiently well developed. Transport from south to north is greatly facilitated by a new road built for the R.A.F. during the war. The north side of the island is very sandy and has little or no algal growth.

BENBECULA (O.S. 23, 32)

This island consists of stretches of peaty moorland

separated by innumerable fresh and salt-water lochs. Sandy stretches occur between South Uist and North Uist, in which small rocky areas occur. On these rocks Fuci grow and just above the sand, patches of Gigartina and a narrow form of Chondrus often find a habitat, but the plants are not present in harvestable quantity. The ford to North Uist facilitated the examination of the smaller rocks.

NORTH UIST, HARRIS AND LEWIS

(O.S. 8, 13, 14, 18, 22, 23)

In view of the fact that South Uist and Benbecula were unproductive of harvestable weed and that local information and some geological considerations made it appear improbable that there would be any significant difference over the remainder of this chain of islands, the survey was not continued further north. Carrageen is gathered by housewives and used regularly for puddings, but there seemed no likelihood of commercial harvesting being practicable in view of the apparent uniformity of the ecological factors which would be expected to govern the growth and distribution of the weed over the remainder of the islands of this outer chain.

COLL (O.S. 52)

Coll lies north-west of Mull, on the Atlantic side, in an exposed position, $57\frac{1}{2}$ miles from Oban. The island conforms to the type that has already been described for the Outer Isles. On the north-western side sandy bays alternate with rocky headlands, while blown dunes are flanked on the landward side by 'machair.' On the south-eastern peaty side of the island, the coastline is broken by two large lochs, Breachacha and Eatharna. North-east of the latter, the coast is somewhat sheer and difficult of access up as far north as Sorisdale Bay. Between the two lochs there is a broken rocky coastline. West of Loch Breachacha, Crossapol Bay forms a deep inlet, the ends of which project towards the island regions of Soa and Bhoramuil.

The amount of Chondrus present on the coasts of Coll is negligible, but Gigartina occurs and is collected in August by the crofters for their own use. From Sorisdale Bay south-west to Loch Eatharna, the coast may be deemed inaccessible for harvesting purposes and its configuration makes the presence of Gigartina unlikely except in sparse quantity on occasional small headlands. On the remainder of the coast the rocky headlands which slope gently laterally in undulating boulders to a sandy strand carry a rich algal growth. The *P. canaliculata*, *F. spiralis*, *A. nodosum* and *F. serratus* zones are well marked; rock pools and rocky projections in the *F. serratus* zone show a good cover of Gigartina. The latter occurs in large tufts where the rock is exposed and under the *F. serratus* plants the small dwarfed fronds are to be seen, especially in the higher parts of the zone, a condition which is also familiar in Anglesey and elsewhere. When the lower areas are reached and deeper pools occur, the Laminarias,

Himanthalia and *Halidrys siliquosa* are present in luxuriant communities. Rocky ledges run out into the sand, frequently at the *F. serratus* level, with Laminarias occupying the deeper crevices between the ledges. The frequent occurrence of Gigartina just above or among the Himanthalia at the base of the *F. serratus* zone is a conspicuous feature of these coasts (see also pp. 39-40).

On each of the numerous broad headlands, 100 lbs. of Gigartina could easily be gathered and in the region of Soa, boatloads are gathered locally for domestic use. The island of Coll, however, is very thinly populated, the total number of people being about 180 in 1944. Farm houses and other homesteads are often unoccupied so that the organisation of any regular carrageen harvest would be difficult. In addition, the harvesting month is August, when the crofters are busy with their own crops and labour is very scarce. The lobster fishermen are few and they fish over such a wide coastal area that it is unlikely that they would have time to gather between tides when their lobsters have also to be taken. The crofters collect Gigartina from near their farms for their own use, and the intervening places are too remote to be considered as a profitable harvesting proposition. This is especially true in view of the much more luxuriant growth of carrageen on the neighbouring Isle of Tiree.

TIREE AND GUNNA (O.S. 52)

Tiree lies south-west of Coll, the isle of Gunna standing in the channel between the two isles. The greater part of Tiree consists of a raised beach from 25 to 100 feet high, interspersed with outcrops of various Pre-Cambrian rocks. The 'machair' which occupies the north-western and the west-north-western shores of Coll and the Outer Hebrides respectively, is a much more prominent feature on Tiree. Most of the soil consists of drift sand with a high proportion of calcareous shell. Tiree is probably the most fertile of the Hebridean Isles and most of the island is occupied in peacetime by a crofting population. There is a very small proportion of peaty moorland on which sheep graze, but most of the land carries good cattle (chiefly Shorthorn-Polled Angus, and Shorthorn-Ayrshire) or is cultivated. Horses are also bred very successfully. The coastal regions are formed of wide sandy bays alternating with rocky areas. Tiree differs from Coll in that there are a greater number of large bays and the intervening headlands are also wider. A general preliminary coastal survey has shown that many of the rocky areas bear a good crop of Gigartina and more Chondrus has been observed here than on any other Hebridean Isle. The two weeds are gathered collectively by the local people as carrageen, and in some instances the examination of a random sample from a housewife's store revealed a high proportion of Chondrus. The collectors are aware of the difference between the two algae and consider that Gigartina gives

the better gel. One advantage of Chondrus is that it grows higher on the shore and so can be gathered on tides that would not recede far enough to uncover the Gigartina. Also, the honey-like fragrance of the Chondrus when dry, is appreciated by the housewife. Without exception, August has been the month named as the main collecting period, although some people gather also in September.

The crofters are aware that the maximum growth has developed by August and September, that the extract is at its best, that the dried weed keeps better, and that it is most easily torn from the holdfast at that time. All these facts can be directly correlated with the findings of current researches.

The coastal areas may be divided into :

(1) *Eilean Ghreasamuill to Am Barradhu (S.W. shore)*

Balephuill Bay is extensive and sandy but the remainder of this area consists of rocky zones, alternating with small sandy creeks, the upper parts of which are occupied by small storm beaches formed of very large rounded boulders. The area takes the full force of the Atlantic, much of it is inaccessible and the amount of carrageen on the remainder is not harvestable except on a small domestic scale.

(2) *Am Barradhu to Rudha Dubh (S.E. shore)*

This coast consists of rocky areas broken by the wide sandy stretches of Hynish and Gott Bays. Gigartina occurs in prolific quantity (up to 5 lbs. per linear yard) on the headlands of all the intervening rocky areas and decreases towards the creeks. Plants occur at the base of the *Fucus serratus* zone, either among the Fucus plants or covering protruding boulders, often in unbroken continuity over patches one yard square. Frequently this zone gives place to a Himanthalia zone on the seaward side. The richest points for harvest are :

(a) NEAR HYNISH PIER

This pier was built for the purpose of the construction of Skerryvore lighthouse and on both sides the growth of Gigartina is exceedingly rich (in places, over 5 lbs. per linear yard). The shelter afforded by the stonework of the pier causes a marked increase in total amount.

(b) COAST NEAR HEANISH AND THE BUCHANAN MONUMENT

Rich growth at lower part of *F. serratus* zone.

(c) ROCKY AREAS UNITING THE ISLAND OF SOA TO THE MAINLAND AT EXTREME LOW WATER

This would be an ideal area for ease of harvesting though the material would need careful washing to rid it of adhering sand. Access to the harvestable areas is over firm sand and rocks have to be negotiated only for the actual picking. In some places the sand is bound together by red algae (probably Rhodochorton and *Poly-siphonia pulvinata*), while in intervening rocky

shallows there is a close sward of *Scytosiphon lomentarius* and *Chorda filum*. *Himanthalia* occurs in deeper pools, but the greenish *Chondrus* and darker *Gigartina* form masses that can easily be seen in the distance at low tide. It was ascertained from crofters that an excellent harvest could also be taken around the island itself. Cattle graze there, but there is no homestead on the island.

(d) SOA TO EILEAN LIATH

The headlands carry a heavy crop (up to 5 lbs. per linear yard), decreasing towards the creeks. Harvesting would be less easy than in the Soa area, but carrageen is gathered regularly by the crofters living near the good areas. Where sandy bays occur the driftweed is rich in brown, red and green algae, large plants of *Codium* being a conspicuous feature in August, as well as masses of tangled *Desmarestia aculeata*, the size of footballs. In this area, as in others on this side of the island, a small amount of *Chondrus* is present in the higher pools.

(3) Rudha Dubh to Urvaig

A sandy area in the Gunna Sound, without suitable substratum for carrageen.

(4) Urvaig to Eilean Ghreasamuill

(south of Rudha Chraiginis; northern and north-western shore)

A number of sandy bays break up the coastline, the largest being Hough, Balephetrish, Vaul and Salum. Between Bàrna-sgeir and Ard Mòr, the coast does not carry any quantity of carrageen. There is some fresh water running into the sea bringing down very fine silt and being considerably polluted by sewage. In much of the area the rocks are sand-covered up to the base of the *Ascophyllum* zone. On other parts of the coast, however, both *Chondrus* and *Gigartina* are gathered regularly for domestic use by the crofters. The best areas within this coastal region are An Cleireach, a rocky headland between Salum Bay and Vaul Bay, from the coast near Rudh' an Fhaing to Sgeir Bharrach, from the eastern side of Hough Bay to Rudha Port Bhiosd, the peninsula of Rudha Chraiginis and Eilean Ghreasamuill.

The island of Gunna has a coastline of sandy bays alternating with rocky headlands, but much of the south-west and north-east coast is washed by heavy seas and these areas do not carry harvestable *Chondrus* or *Gigartina*. The remaining shores do not yield good crops; the plants are sparsely distributed.

The small islands off the Tiree coast from Soa to Chreachasdal Mor were seen to bear prolific crops of *Gigartina*, but access to them would have to be by boat in very calm seas and they would probably prove impracticable for harvest.

From the foregoing it is clear that harvestable areas occur on the north-west and south-east shores of Tiree. During the nineteenth century, Tiree was an important centre of the kelp industry and some attempt has been made in recent years to revive the harvesting of brown algae. Driftweed is still used as manure, and sheep may frequently be seen feeding on the newly cast drift. In 1931 the census showed a human population of 1,446, but that number has been reduced, as far as civilians are concerned, during the war years. Tiree is undoubtedly an area from which a good yield could be obtained if harvesters were available. Difficulties of transport would be considerable, especially as there are no public vehicles on the island. Cargo and passenger steamers call relatively frequently, contact with Oban or Glasgow being possible about four times weekly. The carrageen would have to be dried and that is a major difficulty in the frequent mists on all these Hebridean isles. In good areas there is at least 5 lbs. of harvestable carrageen per linear yard of coast.

IONA (O.S. 59)

This island of grey Pre-Cambrian rocks is very close to the rose-pink granite of the Ross of Mull on the south-east. Areas of blown sand occur on the west and north of the island, where sandy bays are broken up by rocky headlands. The remainder of the coastline is rocky. Carrageen is collected for use by the inhabitants all round the island, but the amount that is present would hardly merit any commercial harvesting in peace-time. This is especially true in view of transport and harvesting difficulties. The island attracts considerable tourist traffic in summer and the crofters are also busy with the garnering of their crops.

INNER HEBRIDES

(Mainly Palaeozoic and Tertiary rocks)

Skye and Mull, together with the smaller isles of Canna, Rum, Eigg and Muck form part of the Inner Hebridean chain. Geologically they are very different from the islands already described because they are formed almost entirely of Palaeozoic and Tertiary rocks. No attempt was made to survey Canna, Rum, Eigg and Muck, as transport difficulties would be out of proportion to the amount of carrageen that was reported to

be present on these small and remote isles.* Attention was therefore focused on making detailed surveys of Skye and Mull and the smaller isles close to them.

SKYE

(Map 2 and Appendix III, Table I, pp. 106-119)

As has been shown by Harker (1941) there is great geological range exhibited in the coast-line of Skye.

*Information kindly given by Professor Heslop Harrison.

This was especially important in the present work because it gave an excellent opportunity of studying the varying configuration of the shore which accompanies rock changes and to observe any effects of these changes on the very rich algal flora. The major part of the coast of Skye is formed of Mesozoic or Tertiary rocks. Where the rocks are hard and drop sharply into deep water no harvestable carrageen is present, but where the coast is broken up into bays into which the rivers drain through narrow lochs, good yields may be obtained, as is shown on Map 2. The heads of the lochs are not suitable for the growth of carrageen. They are usually silty and are often occupied extensively by *Ascophyllum Mackaii*. The rocky headlands between the lochs and the coasts of the seaward end of the lochs themselves present in many areas a suitable littoral zone on which *Gigartina* flourishes.

The Sleat district in the S.E. of the island, unlike the major part of Skye, is composed of various Pre-Cambrian rocks. The area is wooded and has a number of crofts, many of which are near the shore. The survey figures show that it is very rich in carrageen from Isle Ornsay to near the Aird of Sleat. In this area, which consists mainly of Lewisian gneiss, the littoral zone slopes gently, with large boulders on which rich beds of *Gigartina* are present, occurring just above the *Laminarias*. Here, however, as in other parts of Skye one of the great difficulties of organising a harvest would be that the harvesting months coincide with those when the crofters are busy with their hay and peat. Whole families are to be seen working in the hayfields, or cutting and stacking the peats into threes, fives, and then into bigger stacks, to dry; a laborious but necessary task for the provision of winter fuel. During the harvest months the light lasts until nearly midnight, but soft mists enfold the crofts much earlier in the evening and outdoor work has to cease. From the Aird of Sleat to Tarskavaig, Moine schists form the coastline which is steep and inaccessible. From Map 2 it can be seen that this area affords an example of correlation between geological formation and presence or absence of carrageen, because the steep and inaccessible rocks of the Moine schists provide no appreciable littoral zone on which *Gigartina* and *Chondrus* can grow. The remainder of the Sleat, together with the islands of Scalpay, Fladday, South Rona and parts of Raasay, is formed of other Pre-Cambrian rocks and has a different shore configuration.

The more southerly parts of Raasay are different in character and are composed of Mesozoic and Tertiary rocks. The Torridonian sandstone never seems to carry a heavy crop, though adjacent igneous rocks to the south-west give a rich yield. Raasay, Fladday and South Rona were surveyed by boat and it was estimated that 15½ tons of weed could be obtained here. All three islands carried heavy crops in certain localities, either of *Chondrus* or *Gigartina*, or of both species. Sometimes the plants grew at the base of the *F. serratus*

zone just above the *Himanthalia*, sometimes they occurred on the larger pebbles of the shingle as they have been similarly located in parts of Wales. Harvesting would be easy by boat, but in practice, difficulties would arise owing to lack of labour. The islands are rocky, with steep cliffs on the east and with broken rocky shores facing Skye. Most of the land is barren, with a short sward of grasses and sedges on which sheep feed, interspersed with much lichen-covered rock. Occasional small protected bays occur, facing south, with much richer vegetation. There are a few inhabitants of Raasay, but on South Rona only one inhabited house remains on the edge of a flowery water-meadow which rises gently from the rocky foreshore. It was expected that even this remaining thatch would shortly be left to be rent by the winds, leaving cattle and sheep as the sole occupants of the island.

Fladday lies close against the north-west shore of Raasay. The water in the narrows between was so still that gleaming belts of large brown weeds could be seen on the whitish rocks beneath. There is only one small settlement of about four houses in which the few inhabitants of the island live.

Skye is much more easy of access from the mainland, by the Kyle of Lochalsh or by Mallaig, than are the Outer Isles. Much of the country is very inaccessible and the survey frequently necessitated using narrow tracks to cross from one part of the island to another. At the same time some of the inhabitants are used to getting a living on the shore, catching lobsters, collecting shell-fish, and fishing, so that it seems possible that a harvest could be organised in some of the richer carrageen areas. This seemed especially true in the Loch Bracadale area, where women and children collected excellent weed and had it drying on the grass within two days of a request from one of the surveyors. The standard of living on the island shows a considerable range and it would appear that in some of the more remote parts where it is not easy to earn a livelihood from scanty crops and the uncertain harvest of the sea, there is a possibility that a carrageen harvest might help the crofters.

MULL

(Map 3 and Appendix III, Table II, pp. 120-127)

The survey of Mull followed that of Skye and the tides were less good for the study of the varied coasts which the island presents. Loch na Keal and Salen bay almost divide Mull into two parts. According to Harker (1941), the north-western area consists of Tertiary basalt lavas, with Mesozoic rocks emerging at some places on the coast. The main mass of the south-eastern part consists of similar Tertiary rocks, with Palaeozoic and Mesozoic strata visible in some coastal regions. In addition there is a granite intrusion, rose-red and grey, which forms the peninsula

of the Ross of Mull. With such a complex geological structure it is not surprising to find great variety in the coastline, both in regard to topography and accessibility. In the north-western area, the richest growth of carrageen occurred on the headlands, around Calgary Bay and around the coasts of Gometra and Ulva. These latter islands would be worth harvesting if labour were available, but the general impression gained on Mull as a whole was that the shortage of labour was particularly acute. This may have been partly due to war-time conditions, but it was evident that in very remote crofts served by no public transport nor even a good road, the

practical difficulties of harvesting would be almost insurmountable.

The coast of the island south of Loch na Keal and Salen bay is broken by the deep lochs Scridain, Buie, Spelve and Don. The two latter bore no carrageen at all but on the south side of Loch Scridain and the south-east side of Loch Buie a good amount was present. Much of the intervening coast is inaccessible but the hard granite of the Ross of Mull and Erraid provided in places a suitable littoral zone for good crops. In other parts of the coast the granite cliffs rose sharply from the sea and were inaccessible.

SOUTH OF THE FIRTH OF LORNE

THE CLYDE SEA-AREA

The geography of this area has been described by Mill (1891). From the south

the channel extends northward, divided by the large and mountainous island of Arran into the narrow Kilbrennan Sound on the west and the wider expanse of water usually termed the Firth of Clyde on the east. Bute, Inchmarnock, and the Cumbraes, smaller islands lying farther north, split up the Channel into narrow sounds which are continued inland by a remarkable series of deep inlets which run northward into the mountainous peninsula of Cowal.

These inlets are Loch Riddon, Loch Striven, the Holy Loch and Loch Goil. The north-western corner of the channel is prolonged into Loch Fyne and the north-eastern corner into Loch Long. "The latter running nearly north is joined from the east at right angles by the shallow estuary of the Clyde, which is the only large river entering the area." The Gareloch joins the estuary on its northern side.

The Clyde sea-area belongs geologically to two distinct regions separated by the line of the Great Fault and the change in the nature of the rocks coincides with a change in the character of the channels as well as of the scenery of the coast. North-west of the Fault, among the slates and schists of the Highlands the typical fjords with their deep rock basins occur; south-west of the Fault the Old Red Sandstone and Carboniferous formations edge the wider and shallower reaches of the firth.

The tidal range at springs in the area is nine or ten feet and the time of high water at springs is about noon.

The predominant red seaweed in the area is *Gigartina stellata*. In a few isolated places a little *Chondrus crispus* occurs, but never in harvestable quantities. *Gigartina* is in some places very abundant; these rich sites usually face south and are exposed to the prevailing winds. In sheltered places such as the long narrow lochs it occurs much more sparsely. Since it forms a wide belt above the *Laminarias*, extending into the *Ascophyllum* zone, it is partially exposed and can be harvested to some extent on almost every tide except when a strong southerly wind banks up the tide at neaps. During the summer, when the days are long, harvesting can be carried out at low tide, both morning and evening; in winter, on the other hand, the weed in the richest part of the zone is rarely exposed in daylight.

The Gareloch, Loch Long and Loch Goil, and the

exposed parts between them and as far as Toward Point were examined in some detail, but except in one or two isolated places the weed was present in only small quantities and it was not considered worth while to examine Loch Striven, Loch Riddon, the Kyles of Bute, or the upper reaches of Loch Fyne. In any case, there are few people in these places.

LOCH LONG, LOCH GOIL AND THE GARELOCH (Map 4 and Appendix III, Table IIIa, pp. 128-132)

The shores of the Gareloch are gently shelving and mainly covered with boulders on which the *Gigartina* grows in tufts as it does also on the extensive mussel beds at the head of the loch. There the zone may be very wide. The weed is fairly evenly distributed but is richer on the west side, averaging about 2 lbs. per linear yard of shore. Some collecting was done by voluntary labour after the survey had been made.

In contrast to the Gareloch the shores of Loch Long and Loch Goil are mostly steep, except where the rivers enter; there, the shores slope gently and mussel-beds are found on which tufts of *Gigartina* grow in a wide zone. Between the steep rocky exposures there are boulder-strewn bays, where the dominant weed in the intertidal zone is *Ascophyllum nodosum*, and under this there may be found small scattered plants of *Gigartina*. Where fresh water enters, even if it is only a trickle over the rocks, the *Ascophyllum* dies out and *Gigartina* becomes dominant at that level (see also p. 35 *et seq.*). The amounts, however, are seldom great enough to warrant harvesting. When the shores are steep and rocky, *Gigartina* occurs in a narrow band just above the *Laminaria* but rarely in quantities sufficient for harvesting.

Near the mouth of Loch Long on both the east and the west sides, but especially on the west, *Gigartina* is much richer. Between Cove and Kilcreggan on the east, harvestable quantities were present, but when this area was surveyed the weed was found to be much overgrown with *Ulva* and *Porphyra* (see pp. 131-132) and the shore was fouled with oil.

COWAL SHORE

(Map 7 and Appendix III, Table IIIb, p. 133)

On the shore between Dunoon and Toward, Gigartina was present only from Inellan to Toward Lighthouse and in small quantities.

KINTYRE PENINSULA: EAST COAST

(Maps 5 & 6, and Appendix III, Table IIIc, pp. 134-136)

The survey was made from Ardrishaig in Loch Fyne, south to the Mull of Kintyre. Most of the coast is rocky or boulder-strewn, but there are a few sandy bays. Gigartina is present on all rocky exposures but is worth harvesting only in the areas shown in Maps 5 and 6, and the tables in Appendix III, pp. 134-136. With one or two exceptions, the rich areas are not near villages, so that commercial harvesting except by boat would be difficult.

A little to the south of the town of Tarbert there is a stretch of coast with up to two pounds per yard of coast but from here south to Skipness the coast is extremely rugged and inaccessible and the yield falls to half a pound per yard or less.

South of Claonaig and Crossaig Bays there is a rocky exposure with a covering of Gigartina which in places is as much as 10 lbs. per yard and some of it can be reached easily. Between Crossaig and Carradale Bay there are no very rich areas but a considerable part of the coast merits harvesting, carrying between one and five pounds per yard of shore. Carradale is a fishing village of several hundred inhabitants and some harvesting has been done in this area since the survey.

From Carradale Bay to Campbeltown areas worth harvesting are few and scattered. On Davarr Island at the mouth of Campbeltown Loch there are several tons of harvestable Gigartina on the east side; in places the yield is as high as seven pounds per yard of shore. Davarr Island is readily accessible and has been harvested regularly since the survey was made.

The richest area of all is found a few miles south of Campbeltown round Ru Stafnish. Below a narrow zone of large boulders there are off-shore reefs up to 100 yards wide, covered with *Fucus serratus* among which Gigartina grows profusely. At the outer edge of the reefs the rocks are often a little higher and are covered with almost pure Gigartina. In many places the reefs are intersected by deep narrow channels in which Laminaria grows and these cannot be crossed except at very low tides. South of Glen Hervie the reefs are farther off-shore and can be reached only by boat. The whole area would be difficult to harvest

except from a boat in calm weather, but would be well worth while working. The estimates given are conservative and in places Gigartina is much richer than 10 lbs. per yard of shore.

From Glen Hervie eastward only few and scattered patches are worth harvesting and west of Carskey Bay the coast becomes precipitous and could not be surveyed.

AYRSHIRE AND WIGTOWNSHIRE :

(i) WEMYSS BAY TO ARDROSSAN

(Map 7 and Appendix III, Table IIIId (i), p. 137)

This coast is formed of sandy bays with rocky headlands between them. On the whole the slope of the shore is gentle. Gigartina is found on the rocky headlands, especially on the stretch north of Portencross where there is an exposure of Old Red Sandstone as there is on the Great Cumbrae, and Gigartina grows richly as in the latter area. There are several good patches also between Seamill and Ardrossan. The coast from Ardrossan to Wright's Island did not merit detailed survey.

AYRSHIRE AND WIGTOWNSHIRE :

(ii) WRIGHT'S ISLAND TO BURROW HEAD

(Map 8 and Appendix III, Table IIIId(ii), pp. 138-139)

In the northern part of this area there are only a few isolated places where Gigartina is worth harvesting. These are from Wright's Island to Girvan Mains, from Girvan to Lendalfoot, and from Dowan Point to Dove Cove.

In the southern part the Rhinns of Galloway are very rugged, but Gigartina occurs richly in places. Luce Bay is mainly sand and shingle, and yields little harvestable weed.

There was rather wide variation in the whole area, in the type of shore, in the access to it and in the positions in the littoral zone of the two algae Gigartina and Chondrus. Detailed notes are therefore added for each locality as an accurate general statement would be impossible. The records are divided up into sections and harvesting could be organised from the following places near which the weed could most easily be collected: Girvan, Ballantrae, Stranraer, Portpatrick Sandhead, Drummole, Port William [see Map 8 and Appendix III, pp. 138-139, where total weights only are given, based on quantity per square yard (see p. 8)].

It was impossible to survey the coast north and north-west of Kirkcolm as neither transport nor accommodation was available in the area. It is not likely to be a very productive district but some material may be found north of Broadsea Bay.

ISLANDS OF THE CLYDE SEA-AREA

BUTE

(Map 9 and Appendix III, Table IIIe (i), pp. 140-143)

Gigartina is very rich on the igneous rocks of the south end of Bute and becomes progressively less rich

up both east and west coasts. North of Etterick Bay on the west and Rothesay Bay on the east it is very poor because the conditions in the narrow Kyles of Bute approach those described already for Loch Long, with

Ascophyllum dominant and *Gigartina* occurring only as scattered plants underneath it.

From Craigmores Pier (east of Rothesay Bay) south to Kerrycroy there are scattered rich patches and several stretches yielded between 8 and 17 lbs. per yard of coast. From Kerrycroy to Kilchattan Bay there is no *Gigartina* in the extensive sandy bays but the rocks between them have a rich covering and one headland where the growth was luxuriant carried as much as 30 lbs. per yard of coast for about 100 yards.

South of Kilchattan Bay and up to Garroch Head the rocky points all give good yields of *Gigartina* (up to 8 lbs. per yard of shore) but the bays between, although they also are rocky, seem to be too sheltered and contain only a little. Going north again from Garroch Head on the west coast there are two long stretches extending to Garrochty Harbour where *Gigartina* occurs in a rather narrow zone just above the *Laminaria* in harvestable quantities. From Garrochty Harbour north there are scattered rich patches on the rocks between sandy bays, carrying from 3 up to as much as 24 lbs. per yard of shore. This extends to Mecknoch, but northwards the slope of the shore becomes more gentle and *Gigartina* dies out among the *Ascophyllum*-covered boulders.

There are two interesting features on this part of the coast. In two stretches between Gallachan Bay and Scalpsie Bay the zone normally occupied by *Gigartina* has instead *Laurencia caespitosa*. This alga formed a very distinct pale yellow band along the rocks. The other feature is in Stravanan Bay where a basalt sill occurs in the middle of a rich stretch carrying 12 lbs. of *Gigartina* per yard of shore. The basalt sill and the basalt boulders beside it had no *Gigartina*, which confirmed similar observations elsewhere and suggested that this particular smooth hard substratum was unsuitable for the attachment of spores. In other parts of the area however, e.g. round the Garroch Head, *Gigartina* was found growing richly on basalt, though there may have been a physical difference in the structure of the rock.

Since the survey was made, considerable harvests have been taken in Bute each year. These have been taken chiefly from the more accessible areas on the east coast from Rothesay to Kilchattan, while the rich areas at the less accessible south end have been relatively neglected.

INCHMARNOCK

(Map 9 and Appendix III, Table IIIe (ii), p. 144)

This island, about two miles long, lying off the west coast of Bute, has considerable stretches of rocky shore round the south end on which *Gigartina* occurs in quantities varying from 1 to 5 lbs. per yard of shore. It decreases on each side towards the north and that end was not surveyed. The island is relatively inaccessible and no harvest has been taken from it.

GREAT CUMBRAE

(Map 10 and Appendix III, Table IIIe (iii), pp. 145-147)

The Great Cumbrae is a rocky island of about ten miles circumference formed mainly of Old Red Sandstone. Except for a few sandy bays, the shore is rocky and is colonised richly by *Gigartina* which forms a wide band above the *Laminarias* and extends up to the *Ascophyllum* zone. The yield is seldom less than 1 lb. per yard of shore, and is usually 5 lbs. or more. The richest areas are those with an exposure between south-east and south-west and growth is particularly luxuriant round Farland Point. A road on the raised beach which surrounds the island makes the shore accessible everywhere and large harvests have been taken every year since the survey was made. An area on Keppel Point has been reserved for research work on *Gigartina*.

WEE CUMBRAE

(Map 7 and Appendix III, Table IIIe (iv), p. 148)

This island lies about a mile south of the Great Cumbrae and is about 4½ miles in circumference. It consists of a series of lava flows and *Gigartina* is present all round the rocky shore. The plants are at their best on shelving rocks where they form a wide band, which is particularly rich on the north-west and south shores where *Gigartina* is the dominant intertidal alga. Where the rocks are vertical or overhanging, and on the boulder-strewn beaches of the east side, it is not worth collecting. On the whole island there was estimated to be not less than 8 tons of *Gigartina*. It has been harvested, though only in part, by small boats from the Great Cumbrae and by the lighthouse staff.

ARRAN

(Map 11 and Appendix III, Table IIIe (v), pp. 149-151)

This island is about 20 miles long and 60 miles in circumference. The shores are chiefly rocky or boulder-strewn with a few sandy bays. The rocks are chiefly sandstones with igneous sills and dykes. Since there was a rocky coast exposed to the south it was expected that *Gigartina* would be rich there but, although it occurs round most of the shore and is rich in small scattered areas, it is poor along the south coast. Here a series of long dykes stretch for some hundred yards into the sea and these are associated with coralline pools in which tufts of *Chondrus* grow. *Gigartina* is scarce here. Only in a few places in Arran does the quantity of *Gigartina* rise above 2 lbs. per yard of shore, but north and south of Machrie Bay and at Bennan Head, there are short stretches of coast with up to 10 lbs. per yard. A road runs fairly close to the coast round most of the island, and the richer areas are fairly easy of access. In many places, especially on the west and south, the zone normally occupied by *Gigartina* is colonised by *Laurencia* instead (see above).

Gigartina is poor around the more sheltered north end of the island. An interesting point is the occurrence of large quantities of *Ascophyllum Mackaii* in the upper

part of Loch Ranza at the north end (see also p. 13).

A little harvesting was done by voluntary labour on the island.

MAINLAND COAST FROM MULL OF KINTYRE TO OBAN

(Maps 5 & 6, and Appendix III, Table IV, pp. 152-153)

Although Gigartina is decidedly poorer on this coast than inside the Clyde sea-area, its use in the kitchen is much better known. Very often the inhabitants said that it was abundant, and though this is true when only household supplies are considered, there is not enough for a commercial harvest. Occasionally, however, especially on Islay and Jura, lobster fishermen described it as very common in certain places where it was not estimated as rich during the survey, and it is possible that a better ebb would have revealed more.

The west coast of the Kintyre peninsula consists of sandy stretches with rocky exposures between them. The latter are chiefly mica schists and schistose grits. The shore is gently sloping but the tidal range (3-4 feet) is much less than inside the Clyde sea-area so that the littoral zone is much compressed. Where Gigartina occurs it is usually found in scattered tufts among the *Fucus serratus*, but it is not worth harvesting anywhere on this coast. With a southerly or westerly wind it is hardly uncovered even at springs; a suitable ebb for collecting occurs only with northerly or easterly winds. The weed is well known to a few lobster fishermen and housewives and is collected in small quantities for domestic use.

North of the Kintyre peninsula the coastline is broken by a series of long shallow sheltered lochs, West Loch Tarbert, Loch Killisport, Loch Sween, Loch Crinan,

Loch Craignish, Loch Melfort and Loch Feochan. In these lochs, Gigartina is practically absent although a little may be present on rocky ground seldom uncovered even at springs. In rather deeper water, in some of the arms of Loch Sween, small patches of *Chondrus* are to be found.

On the rocky coasts between the lochs as far north as the entrance to Loch Sween, Gigartina is present but only as a very narrow band below the *F. serratus*, amounting to less than $\frac{1}{4}$ lb. per yard of shore. Between Loch Sween and Loch Crinan, however, the quantity increases to between $\frac{1}{4}$ and $\frac{1}{2}$ lb. per yard of shore but the coast is rugged and inaccessible and so harvesting is not worth while. On the peninsula between Loch Craignish and Loch Melfort it occurs in the same way, though there are slightly richer scattered patches. The northern part of this stretch, although rocky, is sheltered by the inshore islands of Luing and Shuna and there is no Gigartina present. The mainland shore continues to be sheltered up to the north of Clachan Sound and the weed does not appear in any quantity until north of Loch Feochan. On the open coast from here to the sheltered Sound of Kerrera it is present in small quantities but is too inaccessible for harvesting.

As Oban is approached the tidal range increases gradually up to about 11 feet at springs. High water at springs varies from about 4 o'clock G.M.T. near the Mull of Kintyre to 5.30 at Oban.

INSHORE ISLANDS

GIGHA (Map 6)

This island off the northerly part of the Mull of Kintyre is about 3 miles long and half a mile wide. The tidal range is small and irregular. On the rocky exposures Gigartina is present but never in quantities which would justify harvesting.

LUING, SEIL AND EASDALE

(Map 5 and Appendix III, Table IV, pp. 153-154)

These islands, which lie close to the mainland north

of Jura, used to be the centre of an important slate industry but only one small quarry is now being worked. The eastern coasts are sheltered and have no Gigartina. The west coasts resemble the exposed mainland coasts and bear on most of the rocky shores from $\frac{1}{4}$ -1 lb. of Gigartina per yard.

The numerous islets which are difficult of access, and the island of Kerrera which was a prohibited area, were not surveyed.

OFFSHORE ISLANDS

ISLAY

(Map 12 and Appendix III, Table V, pp. 154-156)

This island lies about 15 miles from the nearest point of the mainland and is reached by steamer from West Loch Tarbert. The coastal scenery varies from deep sandy bays and gently sloping rocks to precipitous cliffs.

The tides on the north-west coast are much greater than those on the west and south. From Rudh' a' Mhail (Rhuvaal Lighthouse) to Rhinns Point the tidal range is 11-12 feet and on the rest of the coast is only about 5 feet at springs.

Both Gigartina and *Chondrus* are found, but Gigartina is far more common. *Chondrus* is found mostly in

sheltered creeks or in deeper water. Except on the north-west coast the *Gigartina* is exposed only at very low ebbs and forms a narrow zone just above the *Laminaria*, usually mixed with *Fucus serratus*. On the rocky parts of the coast it is present almost continuously but often in such a narrow band that it is not worth harvesting. As in Coll and the Outer Hebrides (*cf.* p. 14 *et seq.*) the weeds occur chiefly on the headlands of north-west coasts.

In the Sound of Islay, *Gigartina* is poor with only short stretches worth working. This condition continues round the east coast and as far as Port Ellen. There are however numerous skerries off the south coast where *Gigartina* is comparatively rich, though a detailed survey was not made of these. The Oa, where the coast is precipitous and not easily accessible by land, was not surveyed. The few miles of rocky coast between the sandy bays of Laggan and Lochindaal bear only about $\frac{1}{2}$ lb. per yard of coast. On the west side of Lochindaal there is a continuous zone of *Gigartina* from Bruichladdich south to Portnahaven, though it is never rich. From Portnahaven to Ardnave Point on the north-west it is present chiefly in sheltered coves. Much of this coast is precipitous and harvesting could only be carried out from a boat in calm weather. The richest stretch of coast lies between Gortantaoid Point and Rudh' a' Mhail, where *Gigartina* occurs in a wide zone but is usually richest in sheltered coves and on the leeward sides of rocks. Between Portnahaven and Rudh' a' Mhail there is always a swell and the rocks could be approached only in fine weather by boat. It is interesting to note that here where the rocks are very much exposed to the full force of the Atlantic the weed is found only in the more sheltered places, in contrast to its wider distribution in the less exposed conditions of the Clyde sea-area (*cf.* Tiree, p. 15 *et seq.*).

JURA

(Map 13 and Appendix III, Table V, pp. 156-157)

The island of Jura, some 28 miles long, lies to the north of Islay and is separated from it by a narrow sound. The east and west coasts are very different. On the east the coast is mainly rocky and the rocks dip steeply into the sea; on the west the coast is more broken with frequent sandy stretches and rocky headlands. On the average the tidal range at springs is four feet greater on the Atlantic coast than in the more sheltered Sound of Jura where it only totals about 4 feet.

The west coast was surveyed only southward from Rudh' ant' Salein at the northern entrance to Loch Tarbert. The north-west coast beyond this is very difficult of access from the land and can be approached by boat only in calm weather and when there is little or no swell. From the ecological point of view it would have been very interesting to find out if this north-west coast, like those of Islay, Coll and the Outer Hebrides, is richer in *Gigartina* than the south-east (see p. 13).

Both *Gigartina* and *Chondrus* are found on the coasts

of Jura but *Chondrus* occurs in much smaller quantity and only in the more sheltered places, e.g. in the enclosed parts of Loch Tarbert.

On the east coast *Gigartina* is present most of the way except in the infrequent sandy bays, but only in a very narrow zone at a low level mixed with *Fucus serratus* just above or even among the *Laminarias*. In places it is associated with *Himanthalia lorea*, as it is elsewhere.

On the west coast it occurs in small quantities on the offshore skerries and on the rocky points projecting into the sea; it is much scarcer in the bays between the points and in the sheltered Sound of Islay. In Loch Tarbert it is poor. On the whole, the amount of *Gigartina* in Jura though sufficient for household purposes is scarcely enough for commercial harvesting.

COLONSAY AND ORONSAY

(Map 14 and Appendix III, Table V, pp. 157-158)

The two islands are joined at low tide by a sand flat and their total length is about 9 miles. The tides are similar to those on the west coasts of Islay and Jura.

The east coast of Colonsay is rocky, with occasional sandy bays and is, especially on the north, difficult of access from the land. *Gigartina* is frequently present, but only in small quantities not worth harvesting. The north-west coast is rugged and can be approached from the land only at occasional bays. In these *Gigartina* is often present in small quantities but the rocks between the bays are precipitous and could not be surveyed. They are not likely to carry any great quantity of *Gigartina*. From Port Mor on the west to Oronsay the coast is more low-lying with numerous islets and reefs offshore.

Gigartina and *Chondrus* occur together at a low tidal level mixed with other weeds such as *Leathesia difformis*, *Fucus serratus* and *Himanthalia lorea*. *Laurencia* occurs here at a higher level than *Gigartina*, instead of replacing it as it does on Bute and Arran. On the whole, the weed is found in the more sheltered coves and inlets on the west.

Much the richest exposures of this area were on the shelving rocks on Oronsay. These rock exposures are continued in a series of reefs and islets off-shore which are probably as rich as the rocks on the shore but can be visited only by boat. They were not surveyed. On the rocky flats at the south-west corner of Oronsay the quantity of *Gigartina* rises in places to 3-4 lbs. per yard of shore, mostly under *Himanthalia lorea*. (The farmer on Oronsay said it was common all round the rocky parts of the island.)

An interesting point is that, in contrast to Coll and Islay, the south rather than the north-west coast is the richest.

The surveys contributed considerably to our knowledge of the ecology of *Gigartina*. A discussion of some of the factors controlling its distribution will be found in the ecology section, pp. 34-41.

II. BOTANICAL WORK

(A) GIGARTINA STELLATA BATT.

TAXONOMY

THE Order Gigartinales has been defined by Kylin (1932) as including those members of the Florideae in which the auxiliary cell, which aids in the feeding of the spores in the cystocarp, is formed *before* fertilisation and is an intercalary cell of one of the vegetative lateral chains of cells which form the thallus. The Order includes a number of families, among which is the Gigartinaceae. In this family, the procarps consist of a large supporting auxiliary cell which bears a three-celled carpogonial branch. The auxiliary cell may produce in addition either a vegetative lateral branch or a second carpogonial branch (Sjöstedt, 1926, p. 47). The genus *Gigartina* was named by Stackhouse (1809) in a paper of which most copies were destroyed in the burning of Moscow in 1812. The name was derived from the Greek word meaning grape-stones, with the Latin adjectival ending signifying "pertaining to" or "of collective significance". In the same volume, Stackhouse also created the genus *Mammillaria*, for *Fucus mamillosus* Good. & Woodw. The latter generic name has since been commonly used to designate a genus of the Cactaceae. A genus *Gigartina* was also proposed by Lamouroux (1813). It was large and contained species which appear to be unrelated, few of which are now considered to belong to the genus *Gigartina* in its present sense. Setchell and Gardner (1933) pointed out that species of the genus have passed successively and temporarily through various genera and, in addition to workers already mentioned, *Gigartina* has been described by Greville (1830), Kützinger (1843) and J. G. Agardh, who in his final revision (1899) brought the number of species up to 69. Setchell and Gardner (*loc. cit.*) bring that number up to 88, one quarter of which occur on the coasts of New Zealand, and one third on the coasts of western North America. The remainder are divided among the Atlantic and Mediterranean coasts of Europe, the north-east of North America, the east and west coasts of South America, the coasts of Japan, Australia, Tasmania and South Africa. *Gigartina* with its numerous species may thus be seen to have an exceedingly wide distribution.

Agardh appears to have regarded the genus as having been originated by Lamouroux. He himself stresses the reticulate filamentous structure of the interior of the frond, and the moniliform threads in the cortex. He defines it (1842) as being separated from other genera of similar habit by the possession of a filamentous pericarpic layer about the compound cystocarp, while it is separated from other genera which also possess such a layer by its superficial and projecting cystocarps

(Setchell and Gardner, *loc. cit.*). Later, Agardh (1851, under *Chondrus*) describes the special pericarpic layer as being a concentric reticulum. In studying the Californian species, Setchell and Gardner found that while some species possess a definite "*pericarpium proprium*" of concentric filaments united into a reticulum, others have little or no trace of it. Some of the latter species appear nevertheless to be members of the genus. These workers suggest therefore that the genus should embrace these forms and that its designation should be modified accordingly, until further work brings additional elucidation. According to Setchell and Gardner (*loc. cit.*) then, Stackhouse's term *Gigartina* is retained, and the genus can be sub-divided into three groups:

- (a) *Pinnatae*
- (b) *Magnifoliatae*
- (c) *Palmatae*

The *Palmatae* have dichotomous or palmate branching and the margins tend to incurve, giving the plant a canaliculate appearance. The margins are usually free from fertile papillae. The plants lack a proper pericarp; their cystocarps are protruding, sessile or pedicellate. This section contains *Gigartina mamillosa* (Good. & Woodw.) J. G. Ag. and its group of related micro-species described by Kützinger (1843) as *Mastocarpus*, and delineated as having the cystocarp (*loc. cit.*, pl. 76, III) without any proper pericarp. It includes also *Gigartina stellata* (Stackh.) Batters. Setchell and Gardner (1933, 1934) stated that in the sub-genus *Mastocarpus* no tetrasporangial sori were known. Subsequently in a letter to Newton (8.2.1938) Setchell wrote that good tetrasporic material of *Gigartina* (*Mastocarpus*) *alveata* had been found in New Zealand. This opened up again the whole question of the possible occurrence of tetrasporic plants in the sub-genus, though *G. alveata* is very different in habit from any of our northern forms.

The species which has been used in Britain for agar production was first named by Stackhouse in Withering's *Botanical Arrangement*, Ed. 3, Vol. IV, 1796, (*e. spec. orig.* in Herb. Linn. Soc.; dispersed in 1863) as *Fucus stellatus*, Stackhouse's *Nereis Britannica*, 1795-1801, being at that time in the press. According to Batters (1902), Withering (1796) rightly considered Stackhouse's *Fucus stellatus excl. syn. omn.* to include his *Fucus echinatus*, which is on the same plate in the *Nereis*, Plate XII, L, (Stackhouse, 1816).

Subsequently, Goodenough and Woodward (1797)

determined and described the plant more accurately under the name of *Fucus mamillosus*. J. G. Agardh (1851) renamed it *Gigartina mamillosa* (Good. & Woodw.) which name persisted until Batters' publication of the original reference (1902). Batters then made the combination *Gigartina stellata*, since Withering's publication of Stackhouse's specific name was one year earlier than that of Goodenough and Woodward.

Setchell and Gardner (1933) in their survey of the North American species of *Gigartina*, separated *G. mamillosa* (Good. & Woodw.) J. G. Ag. from *G. stellata* (Stackh.) Batters. They considered that *Fucus stellatus* Stackh., while undoubtedly united with *Fucus mamillosus* Good. & Woodw. "from the point of view of a 'mega' species, differs in having abundant apical, slender lobes, and may be considered a separate micro-species." A series of specimens which they considered met the requirements of the *Fucus stellatus* of Stackhouse differed "from *Gigartina mamillosa* (Good. & Woodw.) J. G. Ag. (as restricted to typical form) in having the apices cut into 'stellate' narrow divisions, normal in appearance, and not pathological." While not wishing to express any view on extra-British growth forms of the plant, it may be pointed out that around British coasts a similar behaviour of the plant might be due to seasonal development and in any event intermediate forms which link the extreme types can always be found. In this paper therefore, the plant will be described as *Gigartina stellata* Batt., which is deemed to include *G. mamillosa* (Good. & Woodw.) J. G. Ag. (see also Rosenvinge, 1931).

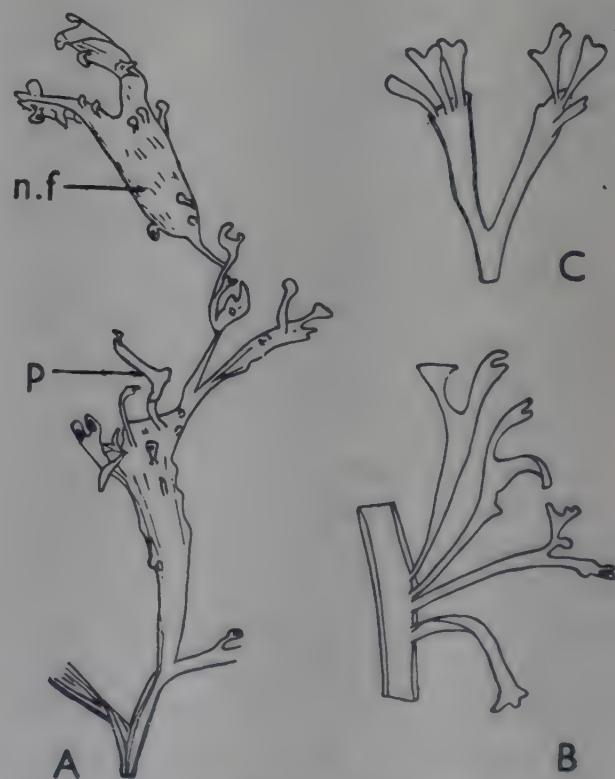
A number of varieties of the species were described by Turner (1808-1819, Vol. 4). The type species *Fucus mamillosus* was that determined by Goodenough and Woodward in 1797, and four varieties were distinguished. The first variety, var. β *linearis*, was described as "frond narrow, linear; apices bluntish and emarginate." The var. γ *prolifer* was distinguishable because the frond was "proliferous at both the disc and margin with very numerous clustered oblong tuberculate processes." In var. δ *echinatus*, the branches were all "dilated upwards nearly naked on one side," while in var. ϵ *incurvatus*, the frond was "nearly linear, apices rounded; peduncles of the tubercles incurved."

Holmes and Batters (1890-91) used the term *Gigartina mamillosa* and listed the four varieties as: f. *linearis* Turn., f. *prolifera* Turn., f. *echinata* Turn., and f. *incurvata* Turn. Batters however, in 1902 called the plant *G. stellata* and included f. *echinata* Turn. in his f. *genuina* and renamed the f. *linearis* Turn. as f. *acuta*, as it had been previously described as var. β by Goodenough and Woodward (1797). He still considered f. *prolifera* Turn. and f. *incurvata* Turn. as distinct forms. Newton (1931) followed the Batters classification in the main, but included f. *genuina* in the type species, and listed only three varieties, var. *acuta* Good. & Woodw., var. *prolifera* Turn., and var. *incurvata* Turn.

Since 1942 large numbers of fresh specimens of

Gigartina stellata have been examined from very varied localities on the west coast of Britain (Map 1) and it is now believed that only one true variety, var. *acuta* Good. & Woodw., can be distinguished. There is a wide range of polymorphism in the species and under certain conditions extreme forms are produced, but these have not been regarded as true varieties. Plate I shows the type species (A and B), the variety *acuta* Good. & Woodw. (C and D), and plants (E and F) which are believed to be growth forms. Subsequent examination of the type species and other specimens at the Natural History Museum, South Kensington, not possible until 1946 owing to war-time conditions, now confirms this interpretation of the type species.

The type species *Gigartina stellata* Batt. is the plant most often found around Britain, and it is distinguished by the *broad segments* to the frond and the regular dichotomy of the branching (Plate I, A and B). It varies from 4-17 cm. in length, and from 3-5 cm. in width. The branching is sparse and the channelling of the frond, which is one of the distinguishing characteristics of the species, is very well marked. The apices of the frond are rounded or wedge-shaped. The surface of the upper parts of the thallus, except in very young specimens, is usually covered with papillae in which carpogonia develop. These latter are not usually marginal. [cf. *Fucus pistillatus* Gmelin=*Gigartina pistillata* Stackh., where the papillae are marginal



TEXT-FIG. 1: GIGARTINA STELLATA BATT. $\times 1$

Regeneration after wounding:

- Specimen from St. David's (December 1944). Shows a new frond (n.f.), which has developed in a similar position to a papilla, and a proliferation (p) behind a damaged apex of the thallus.
- Specimen from Aberayron (January 1944). Proliferation from a wounded margin of the thallus.
- Specimen from the Cumbræ (December 1943). A cluster of fronds is replacing damaged apices.

(Gmelin, 1768)]. The colour of the frond is reddish-brown to black, except when the plant becomes greenish under conditions of strong illumination, or when new vegetative growth is taking place in spring and the newly formed branches of the thallus are deep pink in colour, sometimes turning olive green at a later stage. The plants (Plate I, A and B) are attached to rocks, often in very exposed situations where the coast is surf washed, or grow in rock pools.

Turner described as his var. *γ prolifer*, a plant showing seasonal vegetative growth (1808-1819, Plate 218 e). He illustrated the growth in a narrow form of the thallus, but in the opinion of the present writers, similar growth occurs seasonally in all forms. He included also in this variety a plant showing regeneration after apical injury (1808-1819, Plate 218) similar to those figured here in Text-fig. 1, A and C. As these plants described by Turner are merely stages in seasonal development, they cannot in our view be regarded as representing a true variety. Specimens of similar form have been collected in Wales from Aberdaron (Lleyn Peninsula), rock pools at Aberystwyth and shingle pools at Aberayron, and in Scotland from Moonen Bay (Dunvegan, Isle of Skye), from rocks on a surf-washed coast near Kraiknish (Loch Eynort, Isle of Skye), from the rocks on the Isle of Cumbræ (Buteshire) and from boulders north of Port Logan (Galloway).

Plate 1, B depicts the species as described by Newton (1931) which is regarded here as including the var. *δ echinatus* Turn. and f. *genuina* Batt. It agrees in part with Turner's description of *Fucus mamillosus* Good. & Woodw., but in *Fuci*, Vol. 4, 1819, Plate 218 (a) he figured a type with linear proliferations on which cystocarpic papillae had been formed. This latter has been considered as a growth form in the present work and will be discussed later.

The variety of the plant var. *acuta* Good. & Woodw. is illustrated in Plate I, C and D. It is characterised by the almost linear form of the thallus and the irregular and profuse branching. The branches are often twisted. The length of the thallus is from 4-10 cm. and the width from 0.2-0.5 cm. In Cardigan Bay the whole plant, except the apices of the branches, is often covered by an epiphytic polyzoan *Membranipora pilosa* (L.). The apices of the thallus are often acute. The plant is generally very dark in colour, although greenish specimens have been found under conditions of strong illumination. There are few papillae on the surface of the thallus, but in addition to the carpogonia borne in them, others are sometimes developed in small outgrowths from the edges of the thallus. This form is usually found growing on sand-covered rocks. Specimens were obtained from exposed rocks at Horton (Gower) and Aberporth (Cards.), and also from underneath the plants of *Fucus serratus* L. on Anglesey and at Llanon (Cards.) (Plate I, D). This variety, var. *acuta* Good. & Woodw., includes the var. *β linearis* Turn. (*Fuci*, Vol. 4, 1819, Plate 218 d) as listed by Batters

(1902) and figured here in Plate I, C. This is also the form in which, at Aberayron, many plants have been found with linear papillae (Plate I, D) which on examination have been found to contain spermatangia. These latter plants are the var. *ε incurvatus* Turn. (*ibid.*, Plate 218 n, o) and in consequence of the fact that they always bear spermatangia are not considered to be a distinct variety.

In addition to the above, two growth forms have been distinguished; the first is very distinctive, *parsley-like* in appearance, and is figured in Plate I, E. The thallus is very dwarfed, usually 2-5 cm. in length. It is very irregularly branched, producing a parsley-like growth. It is almost black in colour, but greenish if exposed to strong illumination. Papillae bearing cystocarps partly cover the thallus surface and amongst them are numerous small proliferations. This form always grows in water of low salinity and is often found in localities of sandy shingle beach; possibly the mechanical irritation by angular fragments causes the excessive development of papillae and proliferations.

Specimens were obtained from Aberarth and Aberayron, but the type was also recorded at Port Eynon (Gower), near Dunvegan (Isle of Skye), and at Camas a'Mhòr-bheòil (by the Narrows of Raasay, Isle of Skye). In the last mentioned locality the plants were almost completely buried in the sand.

The other growth form is the *dwarf-form* figured in Plate I, F. The plant, on the whole, is similar to the parsley-type, but is distinguished from it by the sparseness of proliferations and branches, together with its very small size. The thallus is rarely more than 3 cm. long. The papillae which bear the cystocarps are usually borne in tufts at the apices of the thallus. The extremities of the branches are rounded and the thallus is reddish-brown in colour. This form is found growing on rocks beneath constantly dripping fresh water, at the base of the promenade wall at Aberystwyth. It has never been found elsewhere, though search has been made in many other localities.

Both of these growth forms are extreme types of the form figured by Turner (*ibid.*, Plate 218a) and included by him in the type species. The parsley form as described here is extreme in that the proliferations are more numerous and papillae occur not only on their surfaces, but also among them. The dwarf form may be merely the diminutive of this.

It is suggested that in general, the presence of the type species or of the var. *acuta* Good. & Woodw. can be correlated with the habitat in which the plant grows. The broad form of the thallus grows under what would appear to be optimum conditions for the species (see p. 34 *et seq.*). The narrow form is found under less favourable conditions, where it is subjected to very heavy seas and where the water is often turbid with sand. Under such conditions the thallus is often torn and ragged in appearance and the branching becomes irregular as the apices are continually destroyed and

lateral branches replace the main axes. The linear variety would appear to be better suited to such adverse conditions. The parsley form of the type species develops under conditions of low salinity which cause the stunted growth (Rosenvinge, 1931). In addition, the thallus is often half buried in sand. This irritates the surface, so that either excessive branching replaces regular dichotomy or, if the thallus broadens at the extremities, the surface becomes covered with small proliferations amongst the papillae, resulting in the unusual form illustrated in Plate I, E. The type species may be seen to grade into the parsley form from the

lower to the upper part of the zone in the same locality, as is shown in Plate II, B1 and Plate II, B2. These plants were found at Aberayron in a shingle pool with clear water near low water mark, and on shingle higher up the shore, respectively. All grades between Plate II, B1, Plate II, B2 and Plate I, E have thus been found in the same locality. The dwarf form, like the parsley form, has been found only in water of low salinity, but it differs from the parsley form in the sparseness of the branching. This may perhaps be correlated with the fact that the clear water in which it is growing is free from sand.

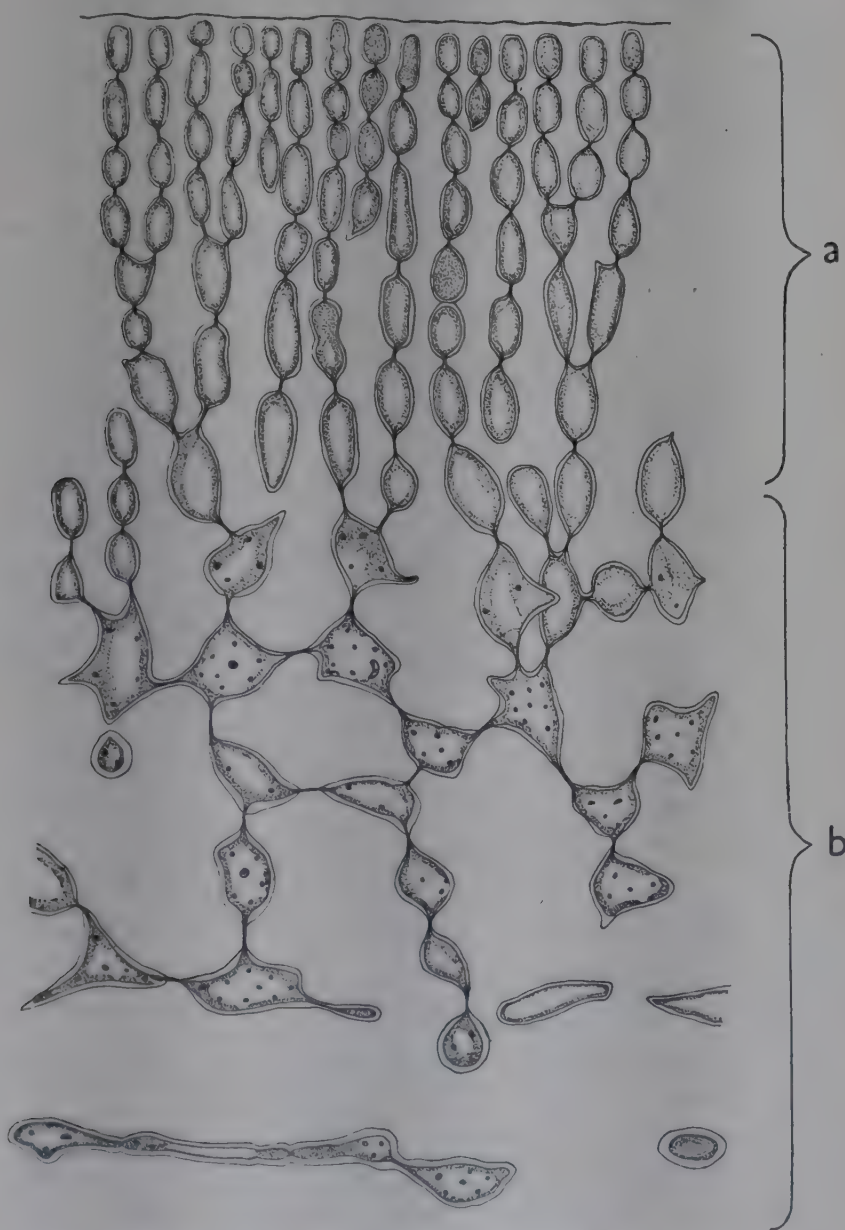
ANATOMY AND REPRODUCTION

Successful long-term harvesting requires a knowledge of the anatomy of the plant as well as of its methods of growth and reproduction. The specimens examined anatomically have been taken mainly from stations reserved for research on the Welsh coast, at Horton (Gower), Aberayron, Aberystwyth and Amlwch, as well

as from the Cumbrae in Scotland, from which last locality monthly samples were obtained. Particular stress has been laid on aspects of the anatomy which are important with regard to the economic use of the plant, such as seasonal changes which are thought to be correlated with the variation in gel strength, ability to regenerate either from an injured part of the upright thallus or from the holdfast, and the method of shedding of the spores. In addition, the vegetative growth and reproductive periods have been carefully observed and recorded. Their importance is obvious from the point of view of fixing the best time of the year for harvesting the crop.

The internal anatomy of the thallus of *Gigartina stellata* Batt. conforms to that of the genus as described and figured by Sjöstedt (1926). He states that "the growth of the frond takes place by means of a bunch of apical cells. A cross section of the thallus shows the tissue divided into a medullary layer of narrow elongated hyaline cells joined to one another by numerous pores and around that a cortical tissue of dichotomously branched anticlinal rows of small rounded cells of regular shape. The cells in the cortical tissue are assimilatory and equipped with chromatophores. Secondary poral connections are rather common in the inner cortical layers" (see Text-fig. 2). Rosenvinge (1931) also agrees with this description in his account of the same species, which he calls *Gigartina mamillosa* J. G. Ag.

A seasonal fluctuation in the gel strength of the extract from *G. stellata* having been found by Marshall and Orr (p. 83 *et seq.*), an attempt has been made by E. A. Lewis to see whether any anatomical changes could be correlated with their findings. It has been observed that new branches and fronds are formed in spring and are conspicuous in May because of their deep pink colour. There is some indication that seasonal fluctuation in temperature causes a variation in the time at which such growth begins and further observations on this point are in progress. As the season progresses the thallus darkens in colour, often, especially in more southerly localities, passing through a phase when the soft wide young growth has an olive-



TEXT-FIG. 2: *GIGARTINA STELLATA* BATT. $\times 330$

Portion of transverse section of thallus showing inner cortical cells with secondary poral connections:

a, dichotomously branched rows of cortical assimilatory cells; b, cells of the inner cortex, with numerous secondary poral connections.

green tinge. (This is not to be confused with the greenish colour which may be observed when the plants have been injured or exposed to unfavourable conditions, e.g. plants occurring in shore pools high in the zone). Later, the young growth becomes more cartilaginous and produces the cystocarpic papillae. Changes also occur in the internal structure of the thallus. In the cortex the number of cell rows increases from an average of 4 to 5 in April to as many as 10 in September. This increases the width of the tissue, the cell walls also become thicker and secondary pore connections increase in number. The cells of the medulla show little seasonal difference except that the secondary pore connections increase and are very numerous by September. This seasonal change in the cortical tissue can therefore be correlated with the increase in the gel-producing property of the plant.

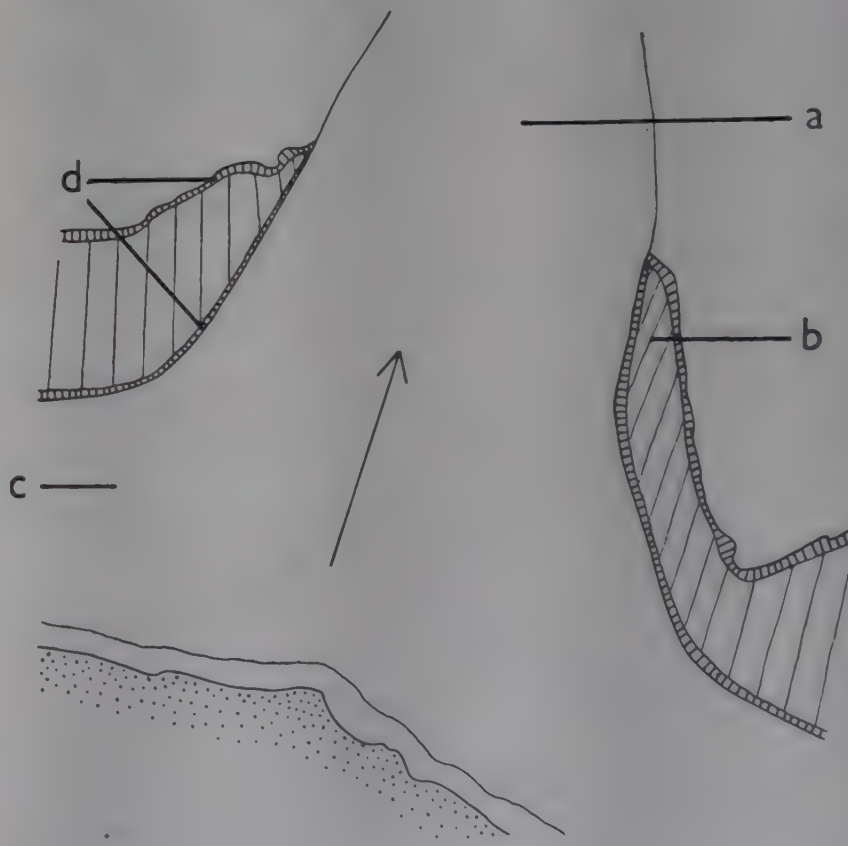
Regeneration normally takes place from the wounded surfaces if parts of the thallus are removed by injury or by harvesting. Consequential changes which may take place in the holdfast will be considered later. Owing to the cartilaginous texture of the thallus, injury to the plants under natural conditions is less common than in more delicate seaweeds, but damaged plants have been found to be capable of forming new branches.

If the apex of a thallus with papillae is wounded, new growth develops from meristems that would normally produce reproductive papillae immediately behind the growing point. The new frond, the distal part of which broadens out, is often in consequence attached by only a narrow band to the parent thallus (Text-fig. 1, A). This type of proliferation also occurs when the injured thallus is immature, in which case it produces a cluster of new fronds immediately behind the apex of the thallus (Text-fig. 1, C). If however, the injured plant is very small (up to 2 cm. in length) and the growth initials of the papillae have not been formed, the apex appears to be able to regrow its meristematic tissues. This has been observed by measuring 50 marked thalli monthly for six months at Horton (Gower). Some regeneration has been seen to take place from the incurved margin of the channelled frond (Text-fig. 1, B), but marginal regeneration is not as common in *Gigartina* as in *Chondrus crispus* (L.) Stackh. An anatomical study of regeneration is in progress.

The holdfast of *Gigartina* has been observed by Lewis to be similar in many respects to that of *Phyllophora Brodiaei* C. A. Ag. (Darbishire, 1896). It is disc-like and in section is seen to be composed of two types of tissue, adhesion, and holdfast (or disc) tissue. The essential difference between these is a difference of function. The adhesion tissue holds the plant to the substratum, while the disc tissue produces the upright fronds. The cells of both tissues are arranged in regular rows, those of the disc tissue often containing food reserves (mainly Floridean starch) and so acting as storage tissue.

Where new fronds are originating from the disc tissue, the cells are elongated and the regular arrangement of cells is obviously disturbed. The adhesion cells vary in shape according to the nature of the substratum. On a flat and fairly regular base (on pebbles at Aberayron (Text-fig. 4, B) and on the sandstone on the Cumbrae), the holdfast is rounded and the adhesion cells lie in regular rows. If the substratum is softer and uneven, the base of the holdfast becomes very irregular, and the adhesion cells form extensions which penetrate into the crevices and so hold the plant in position, as on the porous sand-covered limestone at Horton.* When the holdfast is removed from its anchorage, it is difficult to see these extensions, as most of them are usually left behind on the substratum. Both of these tissues are normally meristematic at the periphery, and so the holdfast increases in size.

The upper surface of the holdfast is covered by a thick 'cuticle' (Olson, 1899) or protective layer, which is yellow in colour under the microscope. The holdfast may be 2-3 layered, each multicellular layer, delimited by a cuticle, being probably the limit of a year's growth. In spring new fronds may be seen originating from the disc tissue simultaneously with the production of soft thin proliferations from the edges of the old thalli.



TEXT-FIG. 3: *GIGARTINA STELLATA* BATT. $\times 30$

Diagram of part of a holdfast in section to show the origin of a new frond from the basal layer of a two year old holdfast. Specimen from Horton (April, 1944)

a, new frond which has grown up through the overlying layer of the holdfast; b, layer of the holdfast ruptured by the growth of the shoot from below; c, basal layer of the two year old holdfast; d, protective layer of the holdfast.

The arrow indicates the direction of growth of the new shoot

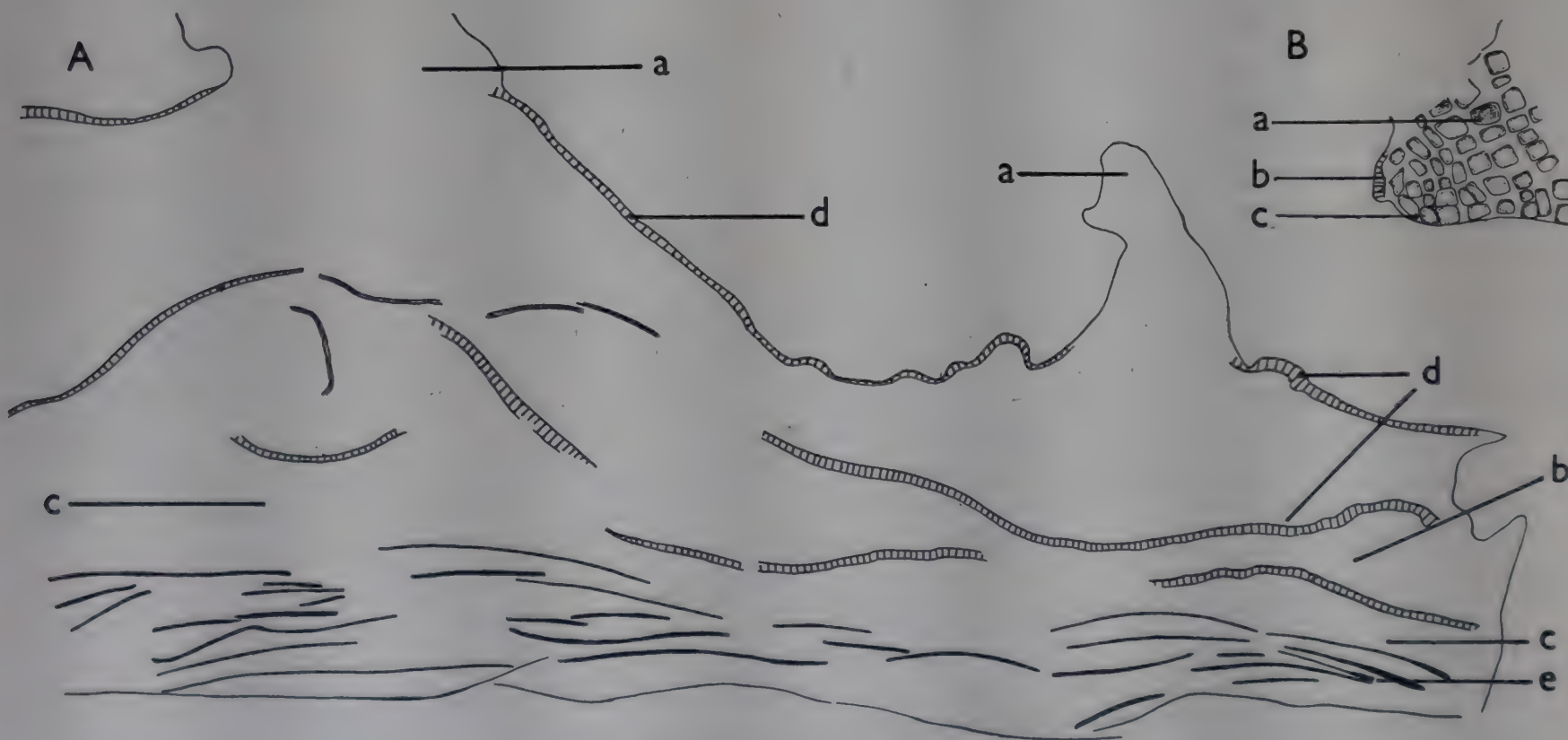
*Fig. (i) B in Ministry of Supply Permanent Record Monograph, No. 11,145.

These new fronds may even grow from layers that have been covered by the growth of the holdfast tissue in a subsequent season. As they grow, they penetrate through the overlying layers to reach the surface (Text-fig. 3). If the plant is worn down in the autumn, leaving only the holdfast, it is still able to regenerate from the latter in the following spring. This is very important from the point of view of harvesting, for except in areas of especially luxuriant growth, *Gigartina* appears to recolonise bare rock very slowly and the destruction of the holdfasts would mean the destruction of the greater part of the subsequent crop for an appreciable time. With careful picking the holdfast need not be damaged; relevant experimental work is described on pp. 42-45.

The age of the holdfast as calculated from the layers of growth varies in different localities. At Aberayron many of the plants growing in the upper part of the mid-littoral zone appear to persist for only one season and to have a single-layered holdfast. Young plants (0.3 cm. long) are a conspicuous feature of this area in spring and it is believed that the scouring effect of the pebbles of the shingle beach is the probable cause of the annual destruction of many *Gigartina* plants in autumn. On the Cumbrae the appearance of the holdfasts suggests that the plants persist for 2-3 years, but at Horton (Gower), especially in the sub-littoral region, the plants may be 3-4 years old (Text-fig. 4, A). In 1943, on the Cumbrae, detached *Gigartina* fronds

formed 50% of the drift (numerically) during late September and October, the fronds being mainly large and cystocarpic. The weakening of the upright fronds as a result of damage by feeding animals, and the effect of seasonal variations in the tensile strength of the fronds due to variations in the structure of the cell walls, are being investigated by H. T. Powell.

Gigartina stellata is described by most authors as a perennial (e.g. Knight and Parke, 1931). This statement is true for a small percentage of the plants in all localities, but most of the plants are believed to be *pseudo-perennials*, though they may also behave as annuals. On the Cumbrae, under what appear to be optimum conditions, the broad form of the thallus develops, the plant behaves as a pseudo-perennial and in September, at the end of the growing season, the upper parts of many of the thalli break away. The holdfast is usually left in position. It has sometimes been observed that patches of rock in a *Gigartina* carpet are left bare. This may be due in part to the weathering of the rock, so that the surface layers and the algae growing on them are torn off by early autumn storms. At Horton (Gower), where conditions as stated previously are less favourable for *Gigartina*, the narrow form of the plant develops. Most of these plants grow near low water mark, but some extend into the sub-littoral zone. The former are usually pseudo-perennial, but the sub-littoral plants are often perennial. Figs. A, 1 and 2 in Plate II show a *perennial* and a



TEXT-FIG. 4: *GIGARTINA STELLATA* BATT.

A: $\times 30$. Diagram of part of a holdfast in longitudinal section to show the layers of growth. Specimen from Horton (March 1943)

a, upright shoots of the current season (Year 3); b, second year's growth; c, first year's growth; d, protective layers of each year's growth; e, debris of the substratum around which the holdfast tissue has grown.

B: $\times 315$. Small portion of a longitudinal section of the holdfast in detail. Specimen from shingle beach, Aberayron
a, cells of the disc tissue; b, 'cuticle' of the holdfast; c, adhesion cell. These cells are regularly arranged, since the holdfast was removed from a smooth substratum.

pseudo-perennial plant from these different depths at Horton.

In all specimens examined *in situ* in various widely distributed localities, a marked vegetative growth has been observed in spring. This growth takes place from the holdfast and from the margins of old thalli as has already been stated (Plate III, B 1 and 2). Later in the spring the new growth darkens in colour, becomes channelled and covered with cystocarpic papillae, so that it is often indistinguishable from old thalli. Sometimes, however, even late in the season, the broad new thalli can still be distinguished from the old fronds (Plate III, D). Observations on isolated marked plants at Horton have shown that from 20-40 small fronds may develop from January to April on distinct persistent holdfasts. These fronds are approximately 0.5 cm. long and develop further only if they are growing in a cluster of 40-50 plants that afford mutual protection against desiccation. When such fronds originate on the holdfast of a plant growing in an algal community, protection is afforded by the

neighbouring thalli of either the same species or of other algae.

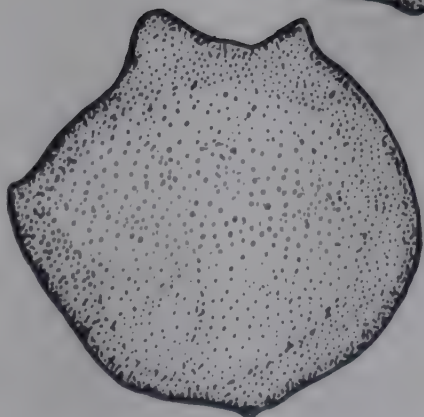
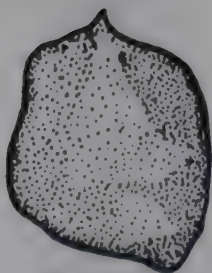
This growth from the holdfast and from the thallus appears to be earlier on the Cumbrae where it is recorded for March. Further south, at Aberporth (Cardigan Bay) and at Amlwch (Anglesey), it usually reaches a comparable stage in April or May. Active spring growth has been observed also in the 'parsley' form at Aberarth and Aberayron, but is less conspicuous because the plants are so much smaller in size. The younger growth stages of all varieties of *Gigartina* are found throughout the year in all localities, but to a much lesser extent than in spring.

Growth continues throughout the summer, although at a much slower rate than in spring and the characteristic papillae develop, mainly on one surface of the thallus. Vegetative growth has been observed even as late in the year as September and October, and if at any time the thallus surface is injured, regeneration may take place from below the injury.

Since tetrasporangia have never been observed, the life-history of *Gigartina stellata* Batt. is still obscure. The only known reproductive organs are carpogonial branches, spermatangia and the unicellular spores formed in the papillae generally assumed to be carpogones. Previous records concerning the structure and occurrence of the sexual organs, particularly carpogonial branches, are rare. Buffham (1896) and Börgesen (1903) refer to the occurrence of spermatangia. A preliminary investigation of the structure of the sexual organs has been made by E. A. Lewis and K. M. Drew.

Good fixation has been obtained by Drew with formalin-alcohol and Karpechenko's fluid. The latter has the merit that it softens the material, whereas it hardens in formalin-alcohol. Possibly on account of the presence of agar-yielding substances in the frond the material hardens further when embedded in paraffin wax, and in consequence microtome sections are very difficult to obtain. Not only is the material hard to cut, but the sections when floated out on water swell and escape from their casing of paraffin wax. As a result of experiment, it has been found that by treatment with warm 10% hydrochloric acid, these difficulties can be overcome. Sections have been stained in Brazilin following the method developed by Drew (1944) for cytological investigations of other Florideae.

Lewis has found that some of the papillae are at first linear (Plate III, C) and if sections of these are examined microscopically, it may be observed that they bear the spermatangia, which occur also on adjacent parts of the thallus. Such plants have been recorded for February and March, but they occur commonly in July and one or two specimens with linear papillae have been found in December (at Aberayron, Cardigan Bay). At the proximal end of the linear papillae bearing spermatangia, sections may show the supporting-cells and carpogonial branches with their trichogynes. Frequently the papillae are not linear but rounded,



TEXT-FIG 5

GIGARTINA STELLATA
BATT.

× 3,100

Filament from the cortex
of a young part of the
frond, showing the devel-
opment of a spermatan-
gium-like cell. (Stain:
Brazilin)

spm, spermatangium-like
cell.

in which case it is believed that only carpogonia develop in them, though the matter needs further investigation. It would appear therefore that some plants produce spermatangia, others produce spermatangia and carpogonia, while others which are far more numerous, appear to bear only carpogonia.

Few details of the development and structure of the spermatangia are available. These reproductive organs are being investigated further and meanwhile an illustration of one of them is given in Text-fig. 5.

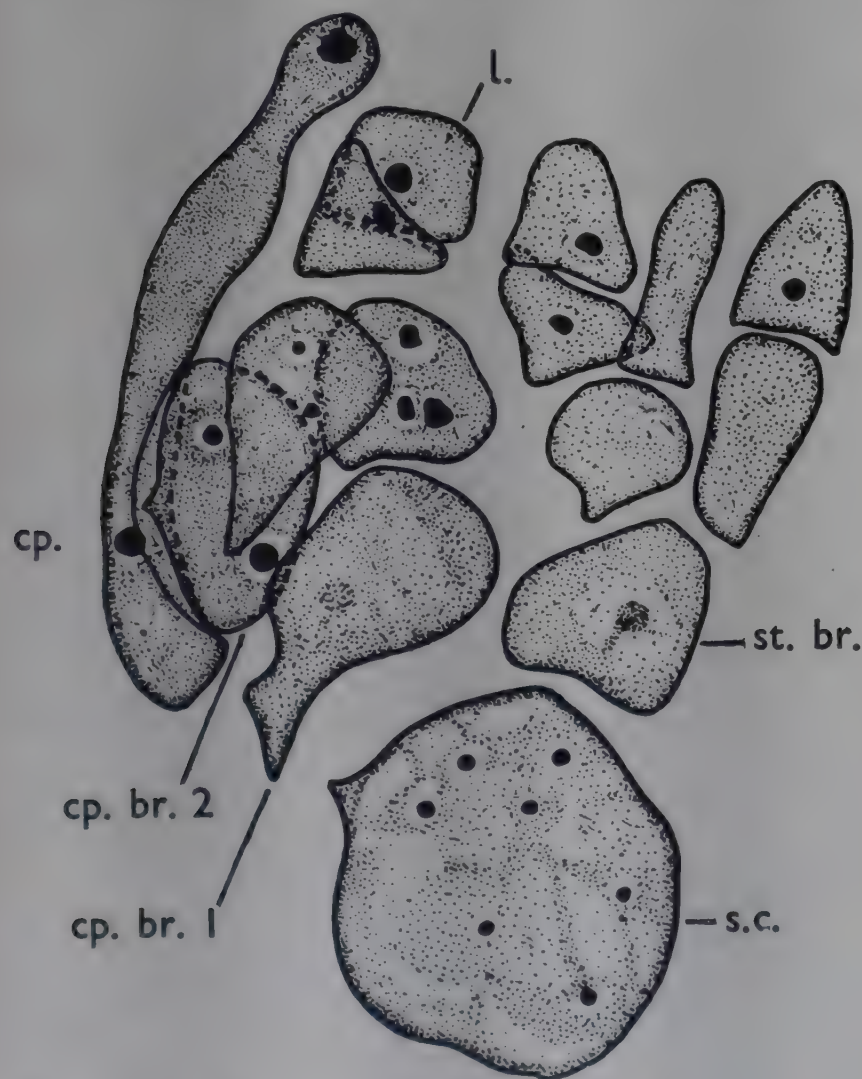
Drew reports that it appears probable that the supporting-cell bears a curved three-celled carpogonial branch typical of the Gigartinaceae, but emphasises that this statement may have to be modified since it is based on exceedingly few observations. Fertile branches are shown in Text-figs. 6, A and B. The supporting-cell also bears either one branched or two sterile branches. The cells of these branches are distinguishable from the cortical cells, among which they lie, by their size as well as by their larger or more numerous nuclei.

The presence of a spermatium adhering to a trichogyne (Text-fig. 6, B) suggests that normal fertilisation will eventually be found to be usual in this alga as in

the majority of the Florideae. In such an event, a reduction division must take place somewhere in the nuclear cycle.

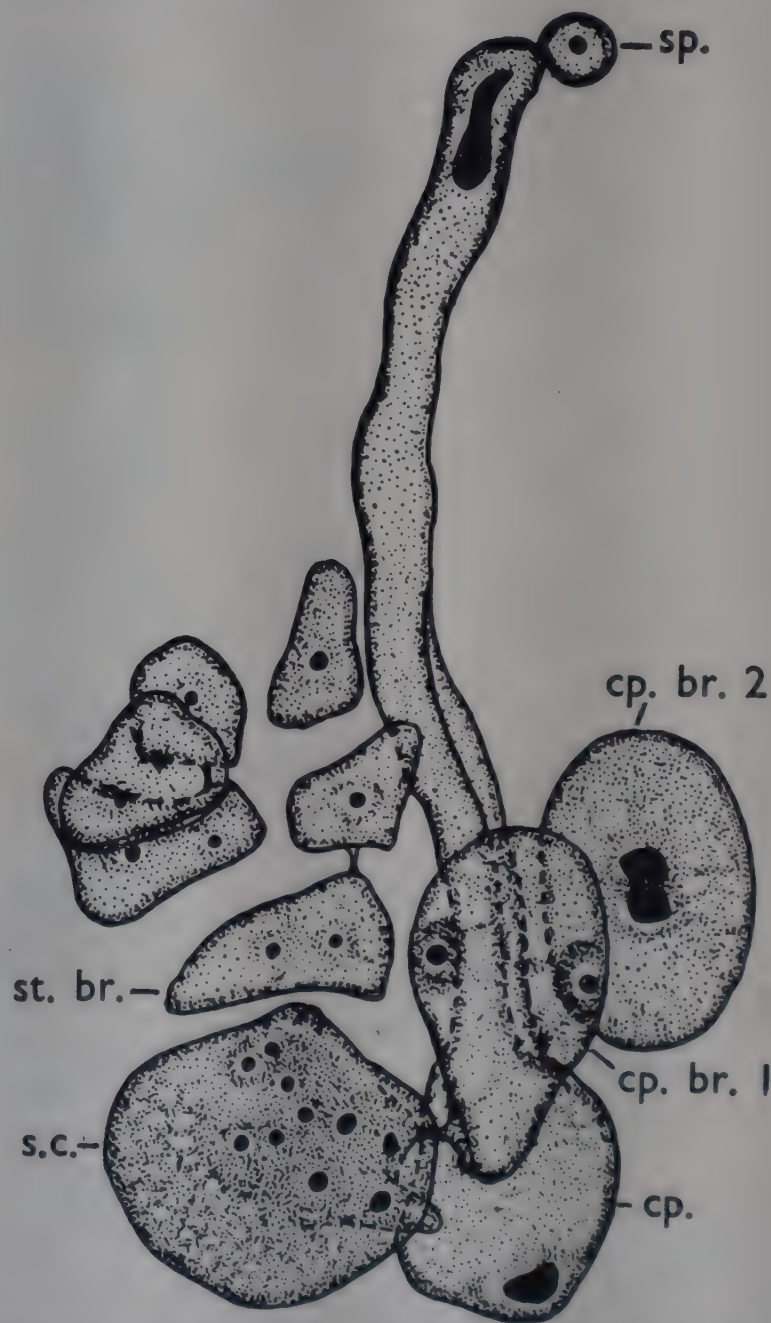
No post-fertilisation connection between the carpogonium and the supporting-cell has been seen. Other sections have shown indications of outgrowths from the enlarged supporting-cell, similar to those figured by Doubt (1935) for *Gymnogongrus platyphyllus* and interpreted by her as gonimoblast filaments. The development of the sporogenous tissue is under investigation.

Lewis has observed that when the cystocarp is mature, the spores escape in mucilage through a lateral ostiole (Text-figs. 7, A and B). The remainder of the cystocarpic papilla then disintegrates although it may persist for some time owing to its cartilaginous texture (Plate III, E). Bacterial infection often sets in after the shedding of the spores. The cystocarps mature in July and August, and the maximum period of spore discharge appears to be from September to December. Formerly,



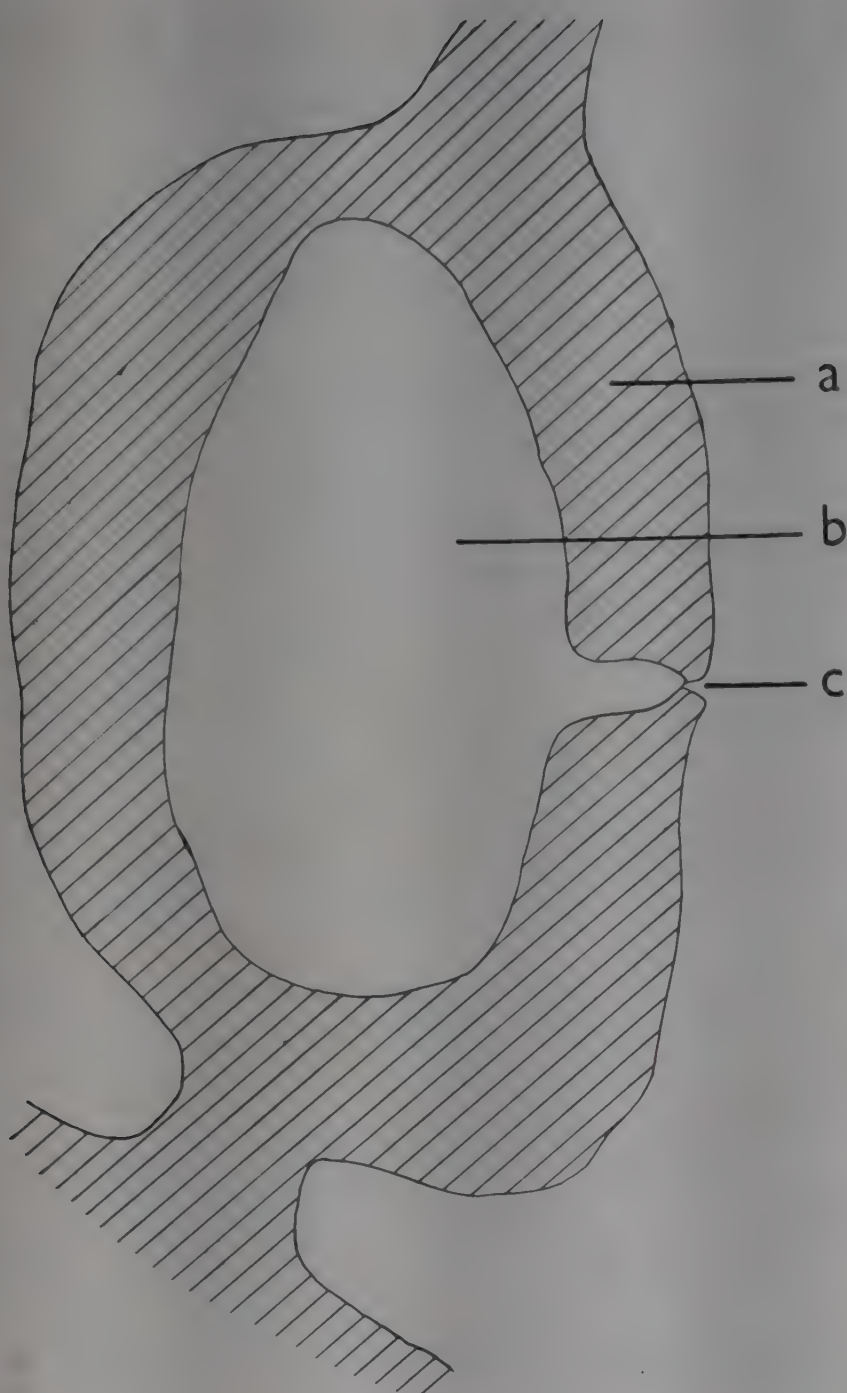
TEXT-FIG. 6, A: *GIGARTINA STELLATA* BATT. $\times 3,000$
Mature fertile branch, showing multinucleate supporting cell bearing a carpogonial branch and a sterile branch.
(Stain: Heidenhain's Iron Alum Haematoxylin)

s.c., supporting cell; cp. br. 1, first cell of carpogonial branch; cp. br. 2, second cell of carpogonial branch; cp. carpogonium; st. br., basal cell of sterile branch; l, cells of lateral branchlets of first cell of carpogonial branch; sp. spermatium.



TEXT-FIG. 6, B: *GIGARTINA STELLATA* BATT. $\times 3,100$
Mature fertile branch with spermatium attached to tip of trichogyne (Stain: Brazilin)

For explanation of abbreviations see Text-fig. 6, A.



TEXT-FIG. 7 : GIGARTINA STELLATA BATT.

A : $\times 40$. Diagram of a longitudinal section of a mature cystocarp to show the lateral ostiole

a, cortical tissue of the thallus; b, masses of carpospores separated by gonimoblast tissue; c, lateral ostiole.

it has been stated incorrectly to take place either by means of a terminal pore (Harvey, 1846-51), or by the decay of the thallus as in *Chondrus crispus* (Chemin, 1937).

Drew has germinated spores freed from the papillae, with the objects of ascertaining firstly whether they grow into microscopic tetrasporophytes or fronds bearing sexual organs, and secondly whether the first nuclear division in the germinating spore is mitotic or meiotic. The first objective was not fully attained in culture but the formation of basal discs was followed in detail and recorded by E. Gonzalez (Text-fig. 8, A, and Plate IV).

The percentage germination of the spores varies considerably from cystocarp to cystocarp. In cases of good germination divisions may take place in up to 75% of the spores, and in the majority of cases about 33% germinate. Occasionally, however, there is no

germination, the spores remaining alive but becoming highly vacuolated. This may be due to immaturity, particularly in cases where the spores have been freed by cutting the papilla.

On germination, the first nuclear division is followed by the formation of a cross wall at right angles to the substratum. Under favourable conditions this stage has been observed as early as 19 hours after liberation, but occurs in greater numbers on slides fixed 36-48 hours afterwards. The cell contents have meanwhile become vacuolated. Of the two cells thus formed, one is often rather larger than the other, and it is this cell which next undergoes division, the wall again being at right angles to the substratum. A similar division then occurs in the smaller cell. It appears that, in general, one of the resulting daughter cells of each division is larger than the other, and all the early dividing walls are perpendicular to the substratum. By further divisions a 6-8 celled disc results. It is one cell-layer thick and is very little larger than the original spore. This stage is normally attained within six or seven days. In these early stages the growth rate has been fairly constant in healthy spores in all the experiments carried out and only subsequently did environmental factors appear to determine the rate of growth.

Lateral increase in size takes place by the development of a number of processes put out from peripheral cells. Although a certain degree of attachment is necessary for germination, the development of these processes appears to be essential for more secure fixation to the substratum, as well as for normal development, since loosely attached sporelings merely form irregular cushions of tissue. A process arises as a protuberance from a single cell of the sporeling, and is soon cut off by a cross wall. This development frequently commences when sporelings are in the 4-5 celled condition. The process grows out, usually parallel to the substratum, into a filament of three or four cells. At the same time the cells of the main body of the spore

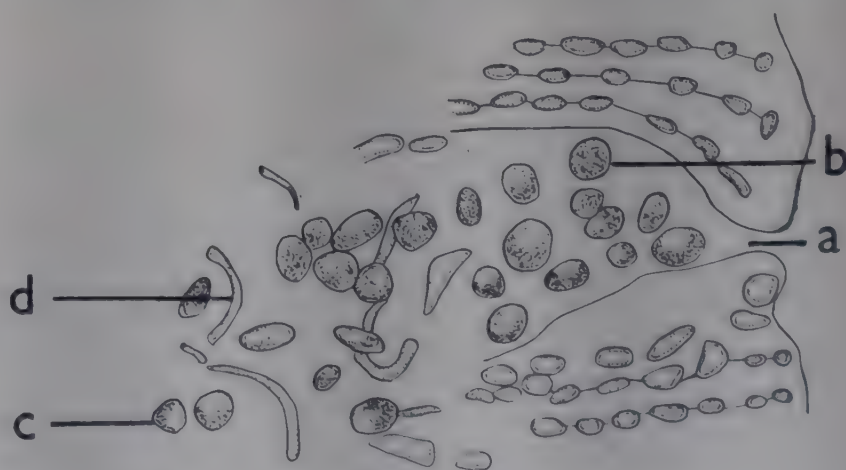
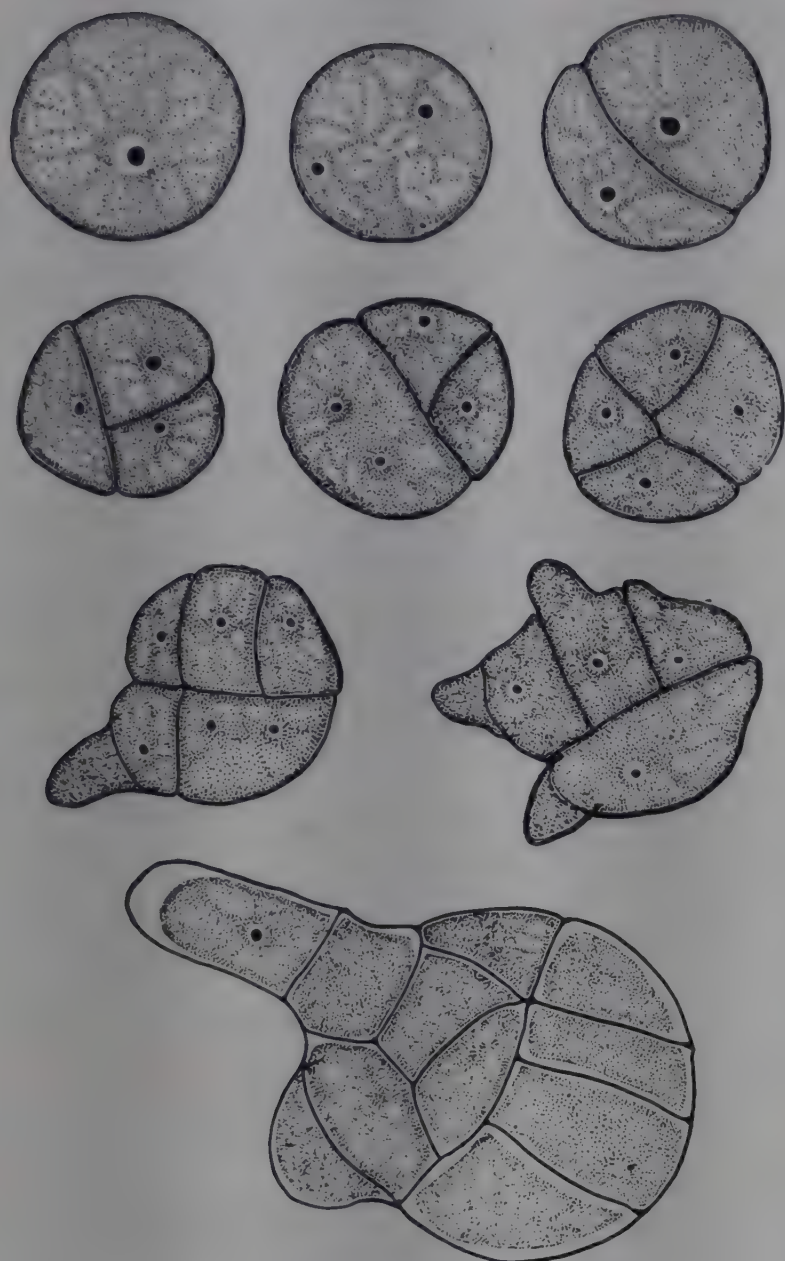


FIG. 7 : GIGARTINA STELLATA BATT.

B : $\times 200$. Portion of a transverse section of a mature cystocarp to show the lateral ostiole

a, ostiole; b, spores aggregated near the ostiole ready for discharge; c, spores inside the cystocarp; d, gonimoblast tissue.



TEXT-FIG. 8, A: *GIGARTINA STELLATA* BATT. $\times 1,700$
Stages in the development of germinating spores

divide by walls parallel to the substratum, resulting in the formation of a disc of tissue one cell thick at the perimeter and increasing in thickness towards the centre. As the perimeter of the disc increases, the process filaments branch in the plane of the disc, thereby bringing neighbouring filaments into contact along the whole of their length and maintaining lateral continuity. The sporeling now consists of a truncated cone of tissue, one cell-layer thick at the periphery but several layers of cells in thickness at the centre; its diameter may be as great as 15 times the diameter of the spore (Plate IV). Under suitable conditions the sporeling may reach this stage within 17 days, supporting Chemin's (1937) statement that this stage is reached after 3 weeks. Later stages in culture have yielded very little further information, chiefly because of an abundant growth of diatoms, but it is of interest to record that sporelings six and a half weeks old may measure 80-200 μ and those of ten and a half weeks about 300 μ in diameter; also, in sporelings in one experiment, aged about 7 weeks, indications of the beginnings of upright thalli have been seen. No reproductive organs have been seen on these discs.

The growth of three sporelings at the disc stage, from spores liberated on May 25th 1945, was recorded over a short period at approximately weekly intervals and the results are given in Table 2.

This account of the germination of the spores of *Gigartina stellata* Batt. agrees closely with those given by Resenvinge for *Phyllophora Brodiaei* C. A. Ag. (1929) and *Ahnfeltia plicata* Fries (1931). In these two latter species, however, growth under the conditions recorded was considerably slower and discs took three months to form.

TABLE 2

GROWTH OF THREE *GIGARTINA* SPORELINGS (A, B & C) AT THE DISC STAGE

DATE	AGE IN DAYS	DIAMETER, μ			CALCULATED AREA, TO NEAREST 100 μ^2			% INCREASE IN AREA / WEEK		
		A	B	C	A	B	C	A	B	C
June 29th	35	76	88	84	4,500	6,100	5,500			
July 6th	42	95	111	110	7,100	9,700	9,500	56	59	71
July 13th	49	113	141	150	10,000	15,600	17,700	41	61	86
July 20th	56	116	153	152	10,600	18,400	18,200	5	18	3
August 3rd	70	151	*	186	17,900		27,200	35		25
August 8th	75	177	*	209	24,600		34,300	52		37

Average (excluding poor week) = 44 60 49

Air temperatures were very high during the week July 13th-20th. During the period of observations, fresh nutrient solution was added on July 1st, 8th, 18th and 29th.

*Diatoms made accurate measurement impossible, but there was considerable growth.

Lewis has observed what appeared to be sporelings 1 cm. high on the Cumbrae in May, and in the upper part of the mid-littoral region at Aberarth. Plants 0.5 cm.-1.0 cm. high were recorded at Horton in February 1944, growing on rock that had been cleared and sterilised in July 1943. Apparent sporelings 0.75 cm.-1.0 cm. high were recorded by E. Conway in July-August 1943, on a quadrat scraped and scrubbed in February 1943 on the Cumbrae.

For the cytological investigation of the first nuclear division in the germinating spore Drew cut up papillae and laid the fragments on slides with a few drops of sea water or nutrient solution. The slides were then placed on damp filter paper in large petri dishes. During the first 12-24 hours, spores rolled out from the fragments in large numbers and healthy ones adhered loosely to the slides. No signs of amoeboid movement were seen. The debris was washed off at the end of this period and the slides submerged in sea water or nutrient solution and fixed at suitable intervals. The spores were stained *in situ* in Brazilin.

The mature spore of *Gigartina stellata*, at the time of liberation from the cystocarp, is spherical in shape, unicellular and measures 12-15 μ in diameter. There is a definite but fairly thin wall surrounding the dense, granular cytoplasm; the latter contains a single nucleus, in which is embedded one relatively large nucleolus. This prominent nucleus is visible, without the aid of any staining technique, in the living cell. The diameter of the nucleus is 0.3 of that of the whole spore and the nucleolus measures 0.3 of the diameter of the nucleus.

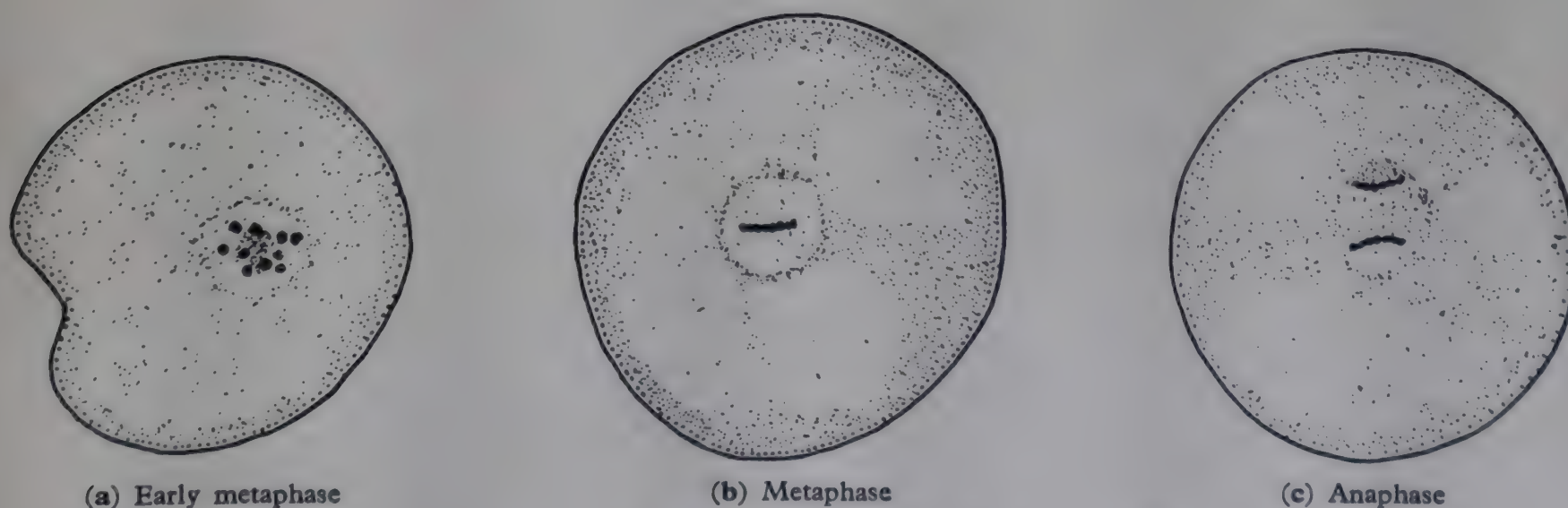
In prophase, the area surrounding the nucleolus appears remarkably clear and devoid of chromatin. Metaphase (Text-fig. 8, B, a and b) and anaphase (Text-fig. 8, B, c) of the first division of the spore have been seen frequently in side view. In this position even an estimate of the number of chromosomes present is out of the question. In one spore, however, the chromosomes had not quite reached the equatorial plate and it was possible to estimate the number present as between

fifteen and twenty. No doubt clearer examples will make an exact count possible, but sufficient is known to state that the first division in the germinating spore is mitotic. Further work is being carried out by K. M. Drew in an endeavour to discover the place of reduction division in the nuclear cycle.

Concurrently with the foregoing, experiments on the development of sporelings on the shore were carried out at Aberystwyth and at Millport. These are discussed on p. 50 *et seq.*

Although a very large number of plants has been examined during the course of this investigation, no tetrasporic plants have ever been identified. The Gigartinales is an Order in which there is a number of abnormal life-histories where the full diplobiontic cycle is not complete. It may be that *Gigartina stellata* Batt. is an aberrant form in which parthenogenesis takes place, or one in which reduction division takes place in the formation of the so-called carpospore; another possibility was that there might be a very small tetrasporic plant which had not been seen, but this is now considered extremely unlikely in view of preliminary results obtained by H. T. Powell from shore experiments at Millport, which are still in progress. Such microscopic tetrasporophytes have been reported by Feldmann and Mazoyer (1937), and J. and G. Feldmann (1942) for the Bonnemaisoniaceae, and by Dammann (1930) for Halarachnion.

In other species of *Gigartina* belonging to sections Pinnatae and Magnifoliae of Setchell and Gardner (1933), tetraspores are known. This is not the only case in the Gigartinales, however, where in one single genus, normal and aberrant forms occur. The same thing may be observed for example in the genus *Phyllophora*. It is also true that in some Florideae, where an isomorphic alternation is normal, tetrasporic plants are much rarer than cystocarpic and may be confined to few localities. This is true, for example, of *Gloiosiphonia capillaris* Carm. which appears to be represented only by cystocarpic individuals on the coasts of France and Denmark



TEXT-FIG. 8, B: *GIGARTINA STELLATA* BATT. $\times 3,700$
The first nuclear division in the germinating spore

(Rosenvinge, 1931), though tetrasporic plants occur as well as sexual individuals on the coasts of Holland (van Goor, 1923). Tetrasporic plants of *Gigartina stellata* Batt. have not been recorded with certainty in any part of the world. Even if they do occur in any other localities, it seems more than likely that in the west of Britain only cystocarpic plants occur. It is difficult to believe that tetrasporic plants, if of macroscopic size, could possibly have evaded the intensive search of the

past five years, but the matter is receiving further attention. The question of the life-history can be solved only in one of two ways, either by growing the spores under controlled conditions, or by a complete cytological investigation. It must be emphasised that the nuclei are exceedingly small in most cells and so present considerable difficulties. The chance of obtaining large numbers of chromosome counts as in some other algae (Drew, 1944) is very slight.

ECOLOGY

The ecology of the plant has been studied both from the point of view of the general distribution of large harvestable areas in Britain, and from the more detailed viewpoint of its occurrence in relation to other shore algae.

The detailed surveys of suitable localities from which large quantities of *Gigartina* can be collected have supplied valuable information about the factors influencing the distribution of this seaweed on the coasts of Great Britain. Map 1 shows that the most productive areas are the coasts of Skye and its associated islands, the west coast of Mull, the coasts of the Firth of Clyde and adjacent islands, parts of Ayrshire and Wigtownshire, Anglesey, the south of the Lley Peninsula and the south of Cardigan Bay, St. David's Head, the Gower Peninsula, the coasts of Devon and Cornwall, and parts of the coast of south-east Scotland and north-east England.

Though *Gigartina* occurs in Northern Ireland in considerable quantity (Anon., 1930-32), transport of the weed to Britain would have been a major wartime difficulty, so the area has not been used for collecting and is not included in the distributional map (Map 1). The Isle of Man was under military control, but it is known that the plant grows there in quantity* and a small harvest was obtained early in the war.

The harvestable areas are confined largely therefore to the west coast of Britain and to the Western Isles. On the east coast of Great Britain extensive sandy

stretches or very steep-sided rocky areas occur, which are unsuitable for a dense growth of *Gigartina*. Parts of the coasts of north-east England and south-east Scotland, however, are exceptions and are topographically suited for the growth of the plant.

Extensive shore survey in Devon and Cornwall, Wales and Scotland has shown that *Gigartina* usually occupies a position on the shore in the lower part of the *Fucus serratus* association and on boulders above the Laminarias. Over much of the coast where harvesting has proved possible, *Gigartina* occurs in discontinuous large tufts on boulders, but in parts of Scotland, as for example on the Cumbraes and parts of Tiree, it forms a closed association and occurs as a continuous dark red belt just above low water mark of spring tides, sometimes as much as twenty yards wide (Plate VII). Such closed consociations of *Gigartina* species have also been observed in the harbour of Skagen by Rosenvinge (1931, p. 512), and have been seen on the Pacific coast by Drew.

It has been reported (Anon., 1939) that in Eire *Gigartina* rarely occupies a definite belt on the shore. This is in accord with the majority of our observations in Britain, though it is in marked contrast to the occurrence of the plant in areas such as the Cumbraes.

It is well known that there are many factors which determine the general distribution of marine algae in any particular locality. The littoral algae can grow only in that position on the shore in which they find the necessary

TABLE 3
SALINITY TESTS

DATE	LOCALITY	DESCRIPTION OF SAMPLE	SALINITY ‰
17.2.43, taken at low water of a spring tide.	Aberayron (Cards.)	a. Shingle pools near H.W.O.S.T.* b. Running water in the mid-littoral region. c. Shingle pool near L.W.O.S.T.†	a. 28 b. 20 c. 26
27.2.43, taken at low water.	Aberarth (Cards.)	a. Running water near H.W.O.S.T.* b. Water flowing over the shingle pools in the mid-littoral region. c. Running water near L.W.O.S.T.†	a. 1·8 b. 13·1 c. 15·4

*H.W.O.S.T. High water-mark ordinary spring tides.

†L.W.O.S.T. Low water-mark ordinary spring tides.

*Information from Dr. M. Knight.

conditions of emergence and submergence to which they are adapted.

In most places the lower limit of *Gigartina stellata* coincides approximately with the low water mark of spring tides, and in some few localities the communities extend into the sub-littoral zone.

Under optimum conditions as on the Cumbræ, the *Gigartina* zone is wide and approaches the *F. vesiculosus* or the *Ascophyllum* zone on the upper side. Where *Gigartina* extends so far up the shore the plants at the top of the zone are usually exposed daily.

Only occasionally is a seaweed found outside its tidal range and this may be because of conditions other than the amount of submergence which are favourable to its growth. *Gigartina* may occur out of its range in the mid-littoral belt in the upper part of the *F. serratus* zone when it is protected from strong light and exposure by the overlapping thalli of the *Fucus*, and is recorded in this position both at Aberystwyth and at Bull Bay (Amlwch). The plants are usually short and the segments narrow but, even if they are more elongated, papillae rarely develop. It was interesting to find that when the *Fucus* covering was removed over a small area at Bull Bay, the *Gigartina* made little growth and the plants remained in the same state until the *Fucus* thalli had regrown from their holdfasts and were long enough to screen them again. The *Gigartina* thalli then became darker in colour and growth in length recommenced. The exposure of the plants had been increased by removing the screening algae and thus growth had been inhibited. There are other instances recorded later of the intolerance of *Gigartina* to desiccation.

Though *Gigartina* is rarely recorded above the mid-littoral belt on the shore, it does occur in such situations, as previously stated, if the sea water which washes over it is of low salinity, as at Camas a' Mhòrbheòil (Narrows of Raasay, Skye), and also at Aberarth

and Aberayron (Cards.) (see also p. 18). Another factor correlated with low salinity is sewage pollution, with a consequent high proportion of dissolved nitrogen compounds in the water. This has been investigated at Aberayron and Aberarth and the results of bacteriological and salinity tests show a very high bacterial count in all cases and a salinity varying from four-fifths sea water down to approximately one-twentieth (see Tables 3 and 4).

At Aberayron, where the *Gigartina* extends unusually high up the shore, the shingle on which the plant is growing is rarely dry, as the drainage water from the neighbouring fields seeps across it to the sea. Under such conditions there is less competition from other species, as the lowered salinity of the sea water, the fresh water seeping across the shore at low tide and the instability of the substratum, inhibit the growth of many other marine algae and a closed *Fucoid* community does not develop. Text-figs. 15 and 16 are detailed quadrats showing the open nature of the community which develops on such an unstable shingle substratum, at Aberayron and at Aberarth, respectively.

When the fresh water of the river Aeron mixes with the salt water it is deflected northwards at high tide by sea currents, thus affecting the area immediately north of the harbour with each incoming tide. In this and other localities of Cardigan Bay where rivers enter the sea in a comparable manner and sea currents deflect the water northwards, *Gigartina* is much more plentiful north of the river mouth.*

Gigartina flourishes on certain exposed and semi-exposed coasts, often occurring on rocks and boulders which present almost vertical faces to the sea, in an intertidal zone of varying width, as at Bull Bay (Amlwch), on the east coast of Jura and the Outer Hebrides. In such localities the distribution is discontinuous and there is much overlapping by the thalli of *Fucus serratus*.

TABLE 4

BACTERIOLOGICAL COUNTS

(Carried out at the Dairy Bacteriological Department, University College of Wales, Aberystwyth)

DATE	LOCALITY	DESCRIPTION OF SAMPLE	PROBABLE NO. OF COLIFORM ORGANISMS PER 100 ML. OF WATER. (2 DAYS AT 37·0° C.)
December 1943. (Winter).	Aberayron (Cards)	a. Water flowing over the Chondrus and <i>Gigartina</i> near L.W.O.S.T.†	a. 1,800 +
July 1944. (Summer).		b. As a.	b. 1,800 +
December 1943. (Winter).	Aberarth (Cards)	a. Water seeping through shingle and over the seaweed.	a. 1,800 +
July 1944. (Summer).		b. As a.	b. 1,800 +

*H.W.O.S.T. High water-mark ordinary spring tides.

†L.W.O.S.T. Low water-mark ordinary spring tides.

* Detailed distribution maps of this area are contained in the Ministry of Supply Permanent Record Monograph No. 11,145 (Maps A and B).

At Horton (Gower), *Gigartina* is usually found growing on the exposed south-western faces of the rocks and is absent from the sheltered sides. The plant usually grows in water that is well aerated and free from mud, hence its frequent association with *Himantalia* on surf-washed coasts. The bay at Aberystwyth receives large amounts of muddy fresh water periodically, which are carried into it by the rivers Rheidol and Ystwyth. This is probably an important factor inhibiting any extensive growth of *Gigartina* on the otherwise suitable rocky shore at Aberystwyth.

Gigartina has also been recorded, though rarely, growing in rock pools in the mid-tidal zone, on sandy shingle among *Fucus serratus*, and among *Fucus vesiculosus*.

Provided that the rocky substratum is suitable for algal holdfast, *Gigartina* will grow on a variety of rocks, as on igneous rocks on the coasts of Skye, Mull, Bute and

near St. David's; on Old Red Sandstone on the Isle of Cumbrae, Bute and north of Girvan in Ayrshire; on shales in Galloway; on schists and gneisses in the Clyde lochs, on the Outer Hebrides and Anglesey; on shales and grits in parts of Cardigan Bay; and on carboniferous limestone in the Gower Peninsula (in part, Smith and George, 1935; Pringle and George, 1937; Pringle, 1935).

The nature of the rock, however, affects the occurrence of *Gigartina* indirectly, in so far as rock structure and composition control to a large extent the configuration and topography of the shore. This is particularly striking on the coasts of some of the Hebridean Islands. On Coll, for example, there are regions where adjacent stretches of coast are either densely covered with *Gigartina* in the appropriate zone, or are completely devoid of the plant. In the first case, the shore rises gently and there are large rocky boulders and pools at the junction

KEY TO THE CHART QUADRATS: TEXT-FIGS. 9-16



Exposed rock surface or a stone



Sand



Shingle



Rock surface covered with
Lithothamnion Lenormandi Foslé



Enteromorpha sp. epiphytic on a
shell of *Patella vulgata*



Holdfast of *Fucus* sp.



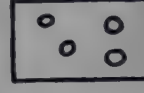
Old stipe of *Fucus* sp.



Balanus balanoides



Patella vulgata



Tubes of *Sabellaria alveolata*

C *Chondrus crispus* (L.) Stackh.
CePn *Chondrus crispus* with epiphytic *Polysiphonia nigrescens* Grev.
Cf *Ceramium flabelligerum* J. G. Ag.
Co *Corallina officinalis* L.
Cr *Cladophora rupestris* Kütz.
Cs *Cladostephus* sp.
Ec *Enteromorpha compressa* Grev.
Fs *Fucus serratus* L.
FseE *Fucus serratus* with epiphytic *Elachistea fucicola* Fries.

FseEc *Fucus serratus* with epiphytic *Enteromorpha compressa*.
Fv *Fucus vesiculosus* L.
G *Gigartina stellata* Batt.
Ge *Gelidium corneum* Lamour.
Hl *Himantalia lorea* Lyngb.
La *Lomentaria articulata* Lyngb.
Lp *Laurencia pinnatifida* Lamour.
Pc *Plocamium coccineum* Lyngb.
Pe *Plumaria elegans* Schmitz.
Rp *Rhodomenia palmata* Grev.

RR *Rhodochorton Rothii* Naeg.
U *Ulva Lactuca* var. *latissima* D.C.
C† Small plant of *Chondrus*.
G† Small plant of *Gigartina*.
† Small plant of either *Chondrus* or *Gigartina* (unidentifiable, 0-1 cm.)
E† Small plant of *Enteromorpha* sp.
F† Small plant of *Fucus* sp.
L† Small plant of *Laminaria* (probably *L. digitata*).
R† Small plant of *Rhodomenia palmata*.

of the *F. serratus* and the *Laminaria* zones. Where *Gigartina* is absent on an adjoining stretch of shore, the rocks rise from the sea as steep or almost vertical cliffs. The weed is absent because the configuration and topography of the shore do not provide the necessary conditions in the appropriate part of the littoral belt. This is in accordance with the occurrence of the plant on Irish coasts (Anon., 1939), where *Gigartina* is recorded as favouring a "rapidly shelving shore" on coasts with "a relatively large littoral zone." In some of the Western Isles of Scotland and especially on the Cumbrae the presence of gently sloping rocky ledges in the appropriate zone appears to be a very important and favourable distributional factor. In some cases, as at Prawle (Devon), a rock change may be accompanied by the presence or absence of *Gigartina* without any obvious alteration in the configuration of the shore. This may be due to microscopic differences of rock structure, affecting its suitability as a lodgement for the developing spores, or conceivably to some chemical effect, though the latter has not been investigated.

Another factor which affects distribution to some extent is the effect of high winds and heavy seas. Though the plant can stand considerable exposure, as is evidenced on the north-west coast of South Uist in the Outer Hebrides and on the surf-washed coasts of Skye and Islay, it is unable, like most other marine algae, to withstand the excessive battering to which it would be subjected on the south-west and western shores of Tiree, for example. This island is unprotected by any land mass and it appears that rocky areas lie beneath the waters towards the Skerryvore lighthouse. The coast in that region shows huge crevices in the rocks piled with enormous water-worn boulders, which are moved freely in winter storms and so effectively prevent algal colonisation of the area. North of Am Barradhu headland (see p. 15) there is some natural protection and still further shelter is provided by Hynish Pier. In this area a rich growth of *Gigartina* has developed, increasing in luxuriance with the additional protection of the pier.

The time of day of low water of spring tides varies in different localities. There is some evidence that where the low tide at springs is in the early morning and evening, *Gigartina* can occur higher up the shore than in places where the maximum exposure period coincides with the hottest part of the day and there is but one exposure in full daylight. This may be another of the factors which favour the development of the wide rich zone on the Cumbrae.

That the plants associated with *Gigartina* on the shore vary, is recorded by various authors in ecological studies of selected parts of the coasts of the British Isles. Cotton (1912) describes the *Laurencia-Gigartina* community on Clare Island, Ireland; Colman (1933) the *Lomentaria-Gigartina* community for Wembury, Dorset; Rees (1935) the *Gigartina* community at



TEXT-FIG. 9

Chart quadrat to show the distribution of *Gigartina stellata* Batt. in a gully near low water mark at Kraiknish, south of Loch Eynort, Skye (August 3rd 1943)

Scale 1 : 12

Substratum: Igneous rock. The gully is surf-washed as is indicated by the presence of *Himanthalia lorea*.

Community: *Fucus serratus*

Type: Closed



TEXT-FIG. 10

Chart quadrat to show the distribution of *Gigartina stellata* Batt. on a sandy reef near low water mark at Aberystwyth (November 12th 1942)

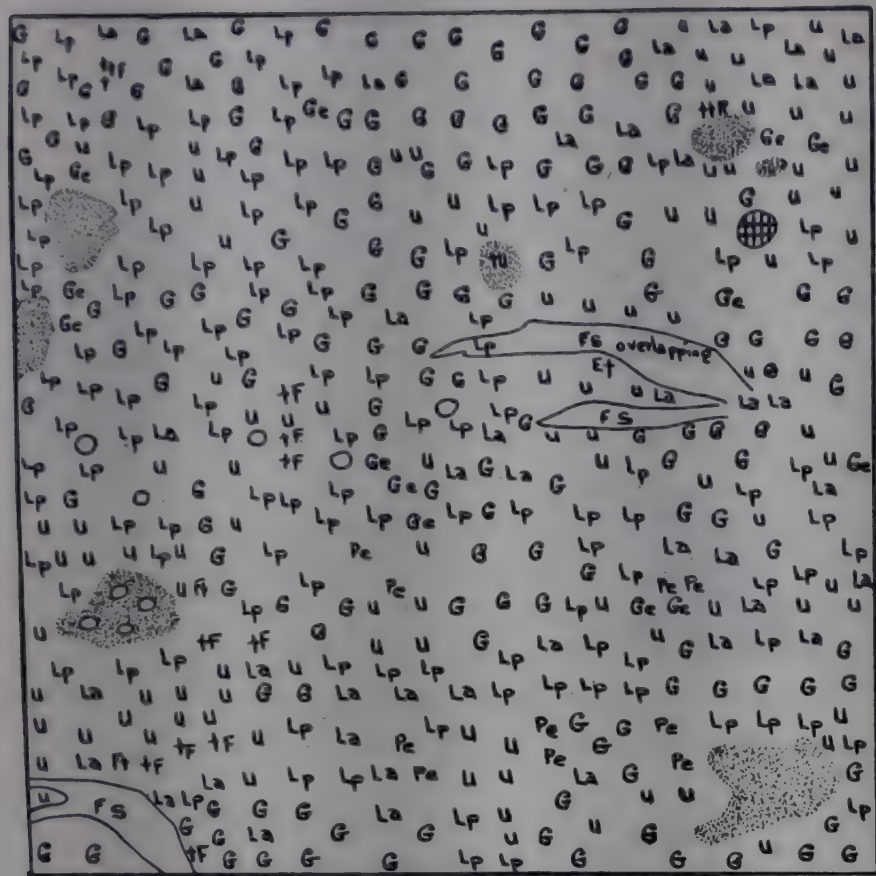
Scale 1 : 12

Aspect: Sloping slightly to the east

Substratum: Sand covered rock. *Fucus serratus* overlaps most of the plants, and *Gigartina* occurs near the *Fucus* holdfasts.

Community: *Fucus serratus*

Type: Open



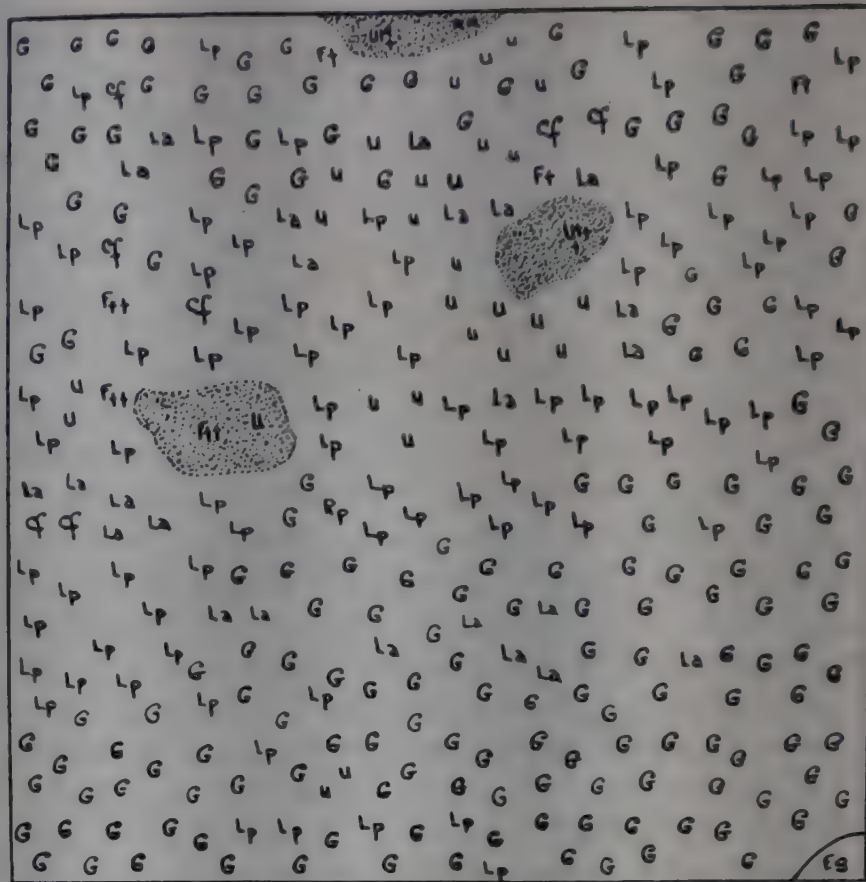
TEXT-FIG. 11

Chart quadrat to show the distribution of *Gigartina stellata* Batt. in a closed *Laurencia*-*Gigartina* community near low water mark at Red Chamber, Rhossili, Gower (January 8th 1943)

Scale 1 : 12

Aspect: South

Substratum: Sand covered limestone rock. The plants of both *Gigartina* and *Laurencia* are small and have a moss-like appearance.



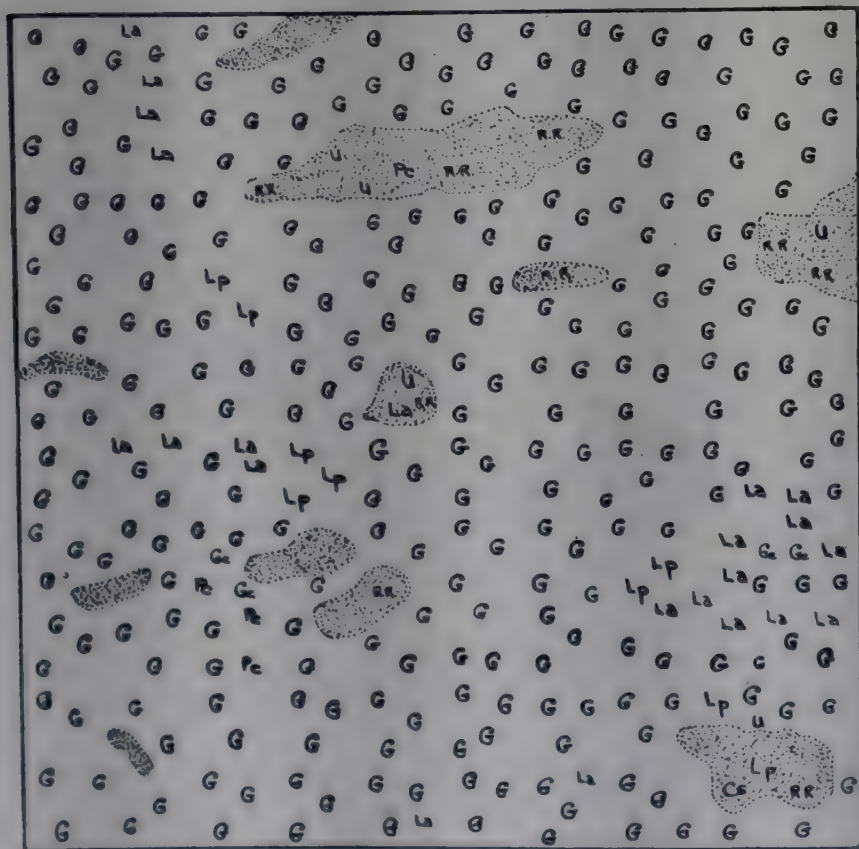
TEXT-FIG. 13

Chart quadrat to show the species associated with *Gigartina stellata* Batt. at the edge of a closed *Gigartina*-*Lomentaria* community at Horton, Gower (March 27th 1944)

Scale 1 : 12

Aspect: South

Substratum: Sand covered limestone rock. This plot is typical of a *Gigartina*-*Lomentaria* community giving way upshore to a *Laurencia* community.



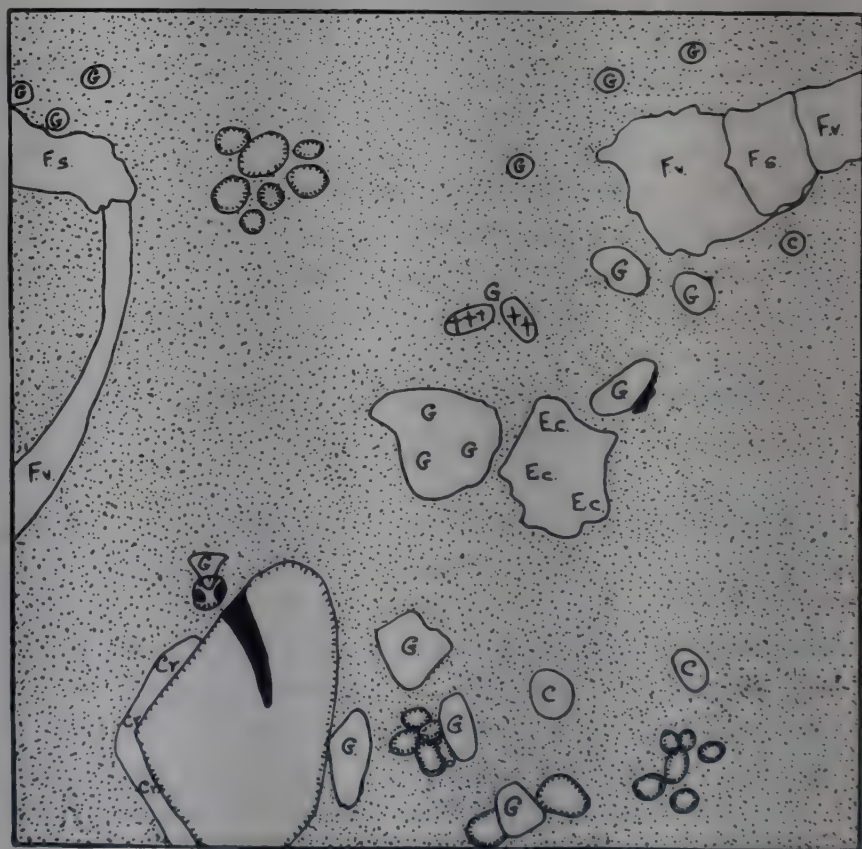
TEXT-FIG. 12

Chart quadrat to show the distribution of *Gigartina stellata* Batt. in a closed *Gigartina*-*Lomentaria*-*Laurencia* community at Horton, Gower (March 27th 1944)

Scale 1 : 12

Aspect: South

Substratum: Sand covered limestone rock. *Lomentaria* binds the sand between the *Gigartina* plants.



TEXT-FIG. 14

Chart quadrat to show the distribution of *Gigartina stellata* Batt. at Camas a'Mhòr-bheòil, Narrows of Raasay, Skye (August 4th 1943)

Scale 1 : 12

Aspect: North

Substratum: Fine shingle almost completely covered with sand. Fresh water flows over the whole of the area mapped.

Community: *Fucus vesiculosus*

Type: Open



TEXT-FIG. 15

Chart quadrat to show the distribution of *Gigartina stellata* Batt. on the shingle beach at Aberayron (September 11th 1942). Lower half of the intertidal zone

Scale 1 : 12

Aspect: West

Substratum: Fine shingle with some larger pebbles to which the seaweeds are attached. The shingle is never completely dry since fresh water seeps through it to the sea. *Chondrus* and *Gigartina* both occur in the area and are often intermingled.

Community: *Fucus vesiculosus*

Type: Open

Lough Ine, Ireland, and Gibb (1939) the *Gigartina*-*Cladophora* community of an area of the Cumbrae. While carrying out field experiments, a detailed study has been made of the plant societies or communities of which *Gigartina* is a component part on many parts of the west coast of Britain. The details of some of these communities within the associations are shown by means of chart quadrats (Text-figs. 9-16), the key to which is on p. 36. All of the quadrats were 1 sq. m. in area.

FUCUS SERRATUS-GIGARTINA COMMUNITY*

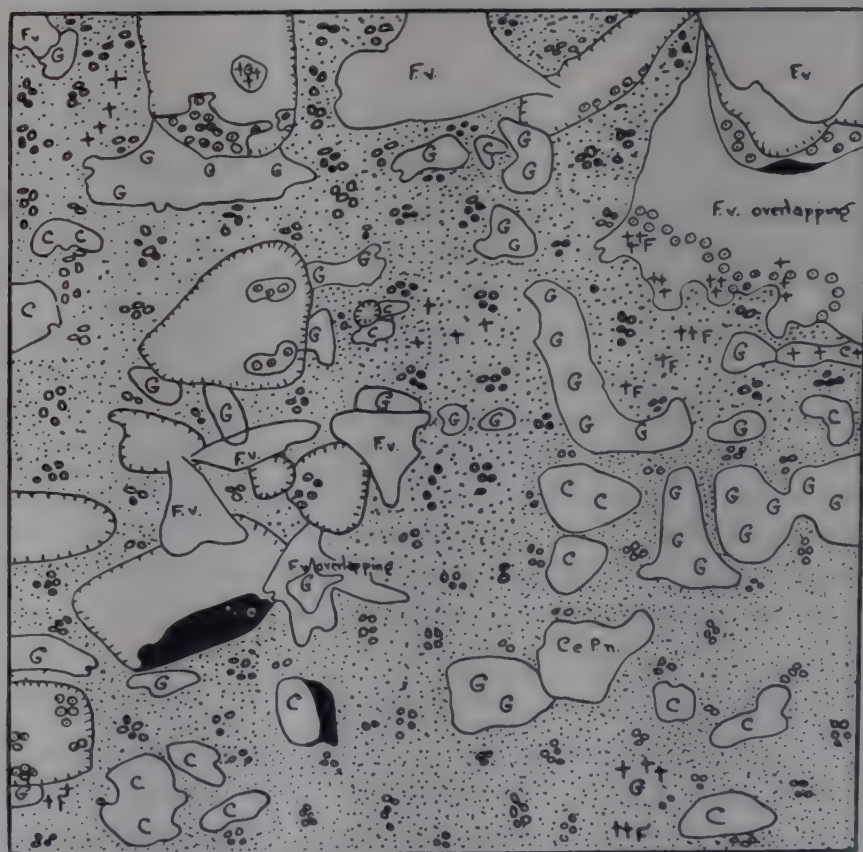
Gigartina has been observed over large areas of the southern and western British coasts forming a secondary community among and beneath *Fucus serratus*, as described by Lyle (1928) for Scapa Flow. This community is often well developed on ledges and boulders or in gullies that are washed with spray, as near Kraiknish (Loch Eynort, Skye). Details of such an actual community are given in Text-fig. 9. The plants are attached to a rocky substratum which affords suitable holdfast for most algae and the community is closed. The plant species often present in addition to *Fucus*

serratus and *Gigartina* are *Laminaria digitata*, *Corallina officinalis*, *Ceramium rubrum*, *Porphyra* sp., *Ulva Lactuca* var. *latissima*, *Rhodochorton Rothii*, *Chondrus crispus*, *Rhodymenia palmata*, *Laurencia pinnatifida*, *Enteromorpha compressa*, *Plumaria elegans*, *Membranoptera alata*, *Lomentaria articulata* and *Himanthalia lorea*. Two animal species often present are *Balanus balanoides* and *Patella vulgata*. Sometimes in this type of community, dwarfed plants of *Gigartina* occur beneath the fronds of the *Fucus serratus*.

Another type of secondary community to *Fucus serratus* is recorded on a sandy reef north of the pier at Aberystwyth. Text-fig. 10 illustrates the distribution of the seaweeds present. Patches of sand occur between the rocks and as these support very little algal vegetation, the community is open. Other species growing with the *F. serratus* and *Gigartina* are *Enteromorpha compressa*, and *Ulva Lactuca* var. *latissima*.

GIGARTINA-HIMANTHALIA COMMUNITY

At Keppel Point on the east side of the Isle of Cumbrae *Gigartina* is found forming an almost pure community immediately below the *Fucus vesiculosus* zone on the shore. In many places a one-metre quadrat would show only a pure *Gigartina* closed association, though



TEXT-FIG. 16

Chart quadrat to show the distribution of *Gigartina stellata* Batt. on the shingle beach at Aberarth (September 10th 1942). Mid-littoral zone.

Scale 1 : 12

Aspect: West

Substratum: Fine shingle with some larger pebbles to which the seaweeds are attached. The shingle remains damp since fresh water seeps across it to the sea. There are few species compared with a rocky coast.

Community: *Fucus vesiculosus*

Type: Open

*Detailed photographs of such a community are contained in the Ministry of Supply Permanent Record Monograph, No. 11,145. (Plates A and B).

plants of *Himanthalia* occur at intervals (Plate VII). This association of *Gigartina* and *Himanthalia* has been observed in many different localities, as may be seen from the Survey Tables (Appendix III, p. 106 *et seq.*), whether the *Gigartina* forms a carpet or is in discontinuous tufts. On the Cumbrae, as on parts of Tiree where a similar closed *Gigartina* community occurs in several localities, the *Gigartina* and *Himanthalia* occur together on gently sloping rocky ledges just above mean low water mark of spring tides. There is considerable exposure and the ecological conditions that favour the growth of *Himanthalia* have been observed in many of the western islands of Scotland to be equally suitable for *Gigartina*.

LAURENCIA-GIGARTINA COMMUNITY

In certain localities communities of *Laurencia-Gigartina* develop between the *Fucus serratus* community and that of the *Laminarias*. This is well seen on rocks at Red Chamber, Rhossili (Gower). Text-fig. 11 shows the distribution of both seaweeds. They completely cover the rock surfaces, often with a moss-like growth, and both the seaweeds remain comparatively small in size. Sometimes, as on Bute and Arran, the *Gigartina* is replaced by *Laurencia*, particularly on sand-covered rocks.

GIGARTINA-LOMENTARIA-LAURENCIA COMMUNITY

In other localities where more sand is present, as at Horton (Gower), *Lomentaria* may partly replace *Laurencia* as the species associated with *Gigartina*. *Lomentaria* is well known as a sand binder and here it stabilises the sand covering the rock surfaces between the *Gigartina* plants and is often found in the sand accumulated around the holdfasts of the plants. Text-fig. 12 shows a typical arrangement of the plant species in such a community, while Text-fig. 13 shows that species other than the dominants intrude into the community. *Lomentaria* may also occur with *Gigartina* on sheltered overhanging rocks.

FUCUS VESICULOSUS-GIGARTINA COMMUNITY

Gigartina grows in the *Fucus vesiculosus* community on sandy shingle at Camas a' Mhòr-bheòil by the Narrows of Raasay, Skye (Text-fig. 14), and at Aberayron and Aberarth, Wales (Text-figs. 15 and 16). In the two latter localities the *Gigartina* is mixed with *Chondrus crispus*. In all three localities the seaweeds are constantly washed by fresh water at low tide.

It is a noticeable fact that a wide zone of *Ascophyllum nodosum* is not usually associated with the presence of well developed plants of *Gigartina* (see also p. 18). It is also true that the presence of *Ascophyllum Mackaii* at the head of a loch is a certain indication that no *Gigartina* will occur.

Except for the narrow form of the plant which grows at Horton (Plate II, A 1) and the type forming the

underflora to *Fucus serratus*, as at Amlwch, *Gigartina* is largely free from epiphytes. Where present, these gain a hold on injured surfaces and on the remains of the cystocarpic papillae after the spores have been shed. The thallus, however, is not easily injured owing to its cartilaginous texture and in general, epiphytes cannot easily gain a hold.

A number of marine animals are frequently associated with the plant and some observations have been made on them, especially on the Cumbrae. Most of the animals which frequent the zone, such as dog-winkles (*Nucella (Purpura) lapillus*), acorn barnacles (*Balanus balanoides*) and the tube worm (*Spirorbis borealis*), cause little destruction, but the limpet (*Patella vulgata*) may cause serious damage. Often, among extensive closed communities of *Gigartina*, bare patches of rock are seen, sometimes quite small but at other times of very considerable size. In these areas it was often found that one or more limpets were present and that the bare patches were limpet 'glades' along which the animals could move and, presumably, devour all the sporeling growths as they did so. This was strikingly shown on two large rocks which were situated in a part of the *Gigartina* zone where the growth of weed was very heavy.

Early in 1943 both rocks were seen to be quite bare on the top, but to have a thick growth of *Gigartina* round the sides. In February 1943, 47 limpets of varying ages and sizes were removed from the bare area on one rock. On the other rock approximately the same number was present but they were left undisturbed. In May and June of that year the untouched rock showed the upper part quite bare except for some *Cladophora* growing on the limpet shells. The rock from which the limpets had been removed was thickly covered with a coating of *Cladophora lanosa*, *Ulva Lactuca* and a little *Porphyra umbilicalis* var. *laciniata*. At the edges of this new growth there were numerous small tufts of *Gigartina* and as the green seaweeds began to die off through the late summer and autumn, the *Gigartina* appeared to be converging inwards on all sides from the already established areas. By late autumn most of the green seaweeds had completed their annual cycle and were washed away. The rock then showed a good deal of *Gigartina* as tufts of low fronds, with many sporelings of *Fucus* showing through (Conway, 1946).

In the spring of 1944 the untouched rock had 30 adult limpets on it as well as a large number of very small ones. The apex of the rock was bare of algae over an area of 90 × 150 cm. The rock from which the limpets had been removed was covered with algal growth except for a small patch in the centre near the apex. The algal growth was almost pure *Gigartina* except in the centre where there were many *Fucus* sporelings and *Himanthalia* 'buttons', as well as a little *Ulva Lactuca* and *Enteromorpha compressa*. The *Gigartina* was healthy, the thalli were thick and crisp,

and the majority of the fronds were 4.5-5.0 cm. long. Later, in the autumn, the rock was almost covered with *Gigartina*, only a very few plants of *Fucus serratus* and *Himanthalia lorea* remaining. Plate VIII shows the striking difference between these two rocks in 1945. *Patella* has been recorded by Orton (1914) as feeding on green algae, and Jones (1946) draws attention to the importance of this mollusc in algal colonisation.

Occasionally in some localities there is a heavy 'spat-fall' of mussels which settles on the *Gigartina* fronds and forms a solid layer between them. The mussels may not survive for more than one season and

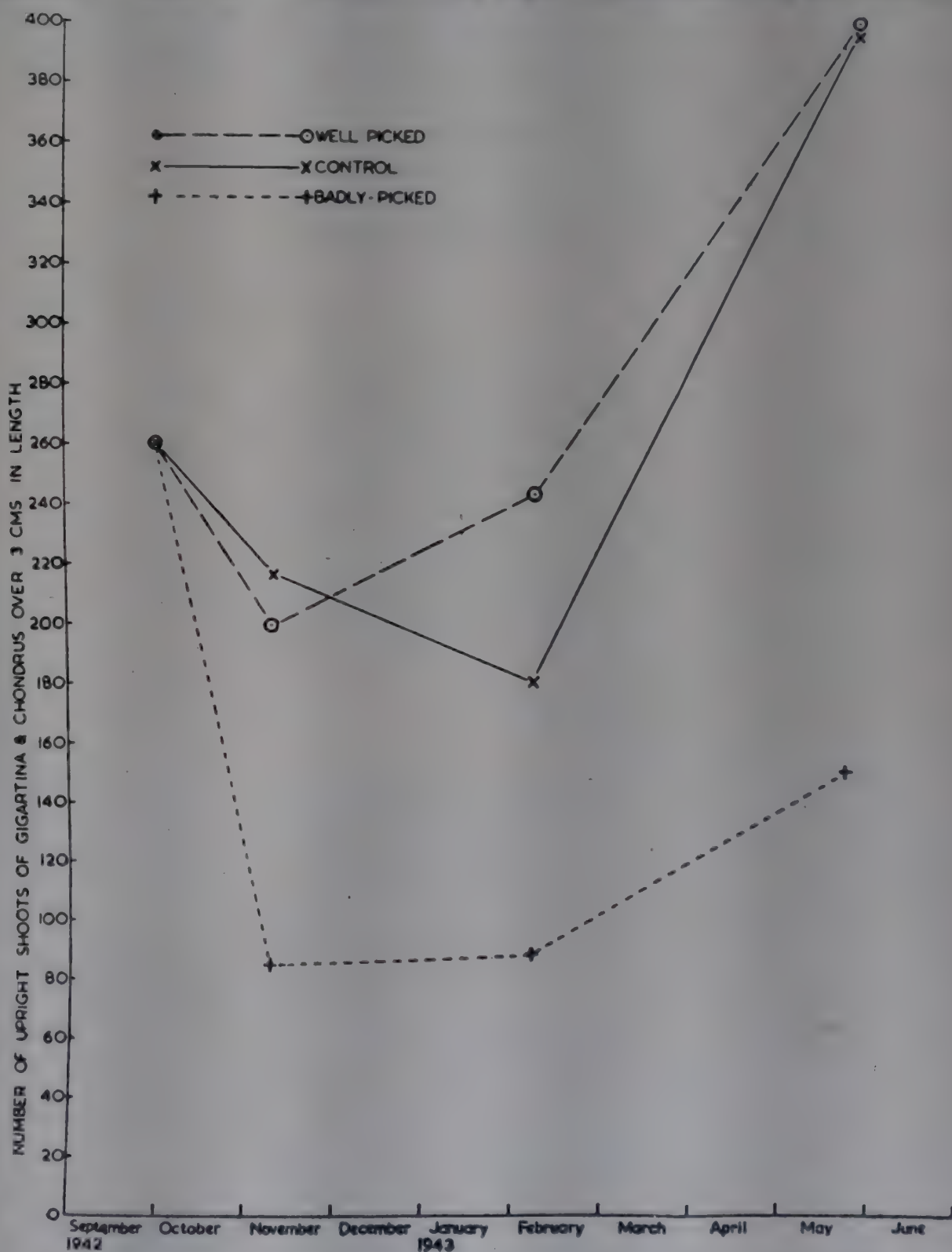
in the following year the weed may be in good condition and free from them.* The presence of the mussels makes the weed unsuitable for harvest, as was the case in the Dartmouth area in 1942 and 1943.

Colman (1933, 1940) gives a detailed account of the fauna associated with *Gigartina* near Plymouth, while Elmhirst (1943) gives a less detailed comparative list of the associated fauna on the Cumbrae and suggests that the marked differences in the fauna of *Gigartina* in these two localities may be because the plant extends much further up the intertidal zone on the Cumbrae than it does near Plymouth.

EXPERIMENTAL WORK

It was necessary to plan a series of experiments on growth and regeneration because the crop of *Gigartina* had to be harvested as soon as possible to meet a

national emergency. It was hoped that the results would enable decisions to be taken regarding the dates when harvesting might be undertaken and also concern-



TEXT-FIG. 17

The effect of different methods of harvesting *Chondrus* and *Gigartina* at Aberayron, where both seaweeds grow together

The results are expressed as the average number of *Gigartina* and *Chondrus* fronds over 3 cm. in length on 1 sq. m. plots, and each point is an average of three plots.

*Observations by Conway in 1947 indicate that a heavy spat-fall of mussels may have a deleterious effect on the *Gigartina* in the following season.

ing the manner of gathering the weed without endangering a future crop. It was also necessary to obtain precise comparative information regarding regeneration after harvesting, the formation of new shoots on unpicked plants and the recolonisation of denuded areas by sporelings.

During the early years of the war, harvesting was organised between May and September. Later, when further observations on the growth and reproduction of the plant had been made, and chemical results on the times of maximum gel strength were available, the harvesting dates were slightly modified. Anatomical work showed that one of the ways in which the shoots regenerated in spring was from the holdfast and consequently, in all localities, an important aim in picking was to leave the holdfast in position. At first, pickers were instructed to take only half of the available material. This was a precautionary measure and in later years a much larger proportion of the available weed was gathered. The results of surveys showed that there were large numbers of plants that were unlikely to be harvested because of the inaccessibility of their habitat. This reserve of plants would, it was hoped, supply the necessary spores for the recolonisation of any denuded areas in the vicinity. The following experiments were carried out:

1. METHODS OF HARVESTING

At first it was not known in what proportions *Gigartina* and *Chondrus* would be available, nor what proportions were desirable from the manufacturing point of view. A preliminary series of experiments was therefore carried out in areas where the two plants grew in approximately equal proportions. Subsequently it was realised that about 95% of the harvest would be *Gigartina*, from the points of view both of availability and of chemical suitability, so all later experiments were concerned with *Gigartina* alone.

Preliminary series of experiments using both Chondrus and Gigartina

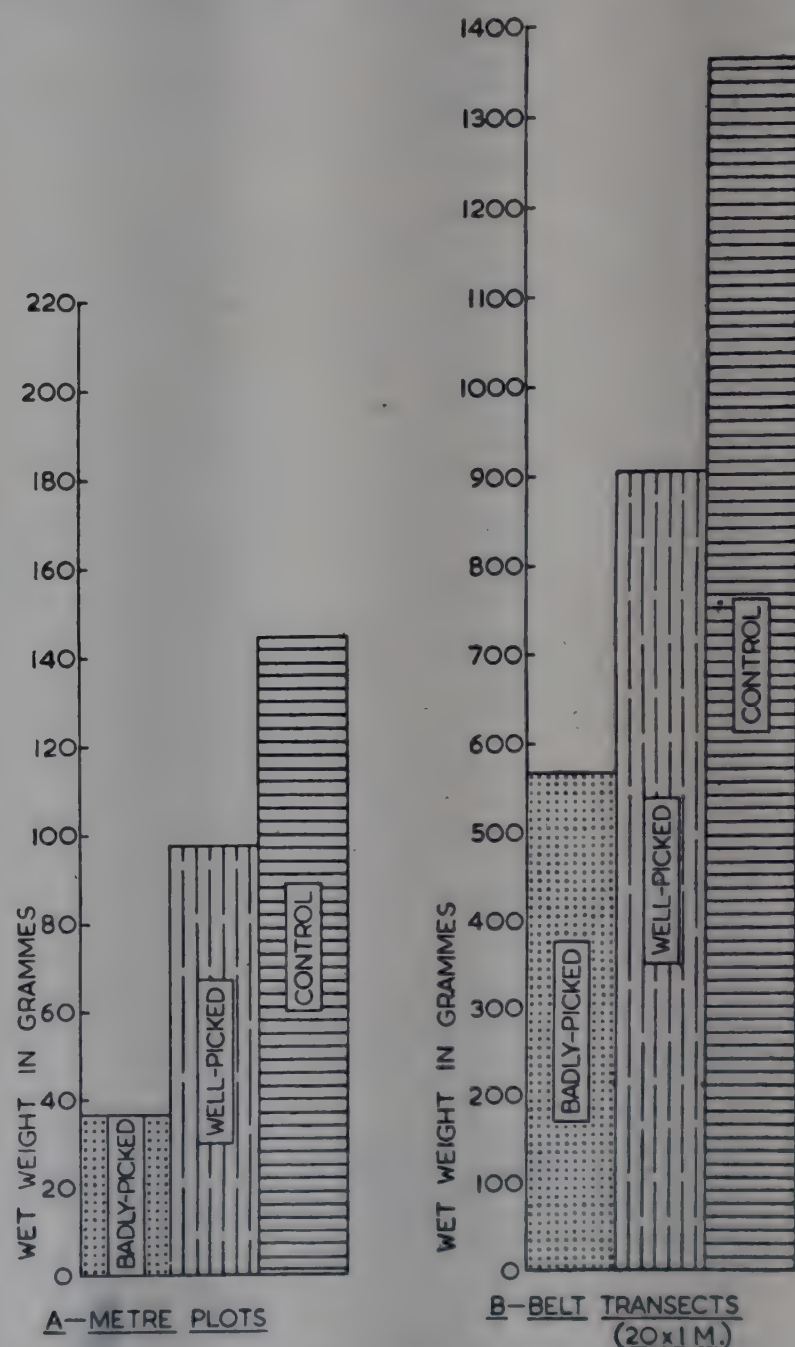
A preliminary series of experiments was carried out on exposed shores at Aberarth and at Aberayron from September 1942 to May 1943, in an area where *Gigartina* and *Chondrus* were present in about equal quantities. The dates were chosen as delimiting the period between two consecutive harvesting seasons. Three 1 sq. m. plots were well picked, three badly picked, and three left unpicked as controls. In addition, three belt transects 20 m. long and 1 m. wide were treated similarly. In this experiment the term 'good picking' is used to mean picking not more than half of the available weed and, as far as possible, leaving the holdfasts in position. The term 'bad picking' means picking all the material and tearing the holdfasts away from the rocks, though it is only on fixed shingle that such a tearing away can easily be achieved. The plots were visited at regular intervals and the results recorded as the number

of upright shoots over 3 cm. in length. In addition, wet weights of weed on the experimental areas were recorded at the close of the experiment.

The results in all cases have shown that the material is sparser from November to February, a period that coincides with rough seas which contribute to the destruction of much algal vegetation. A marked increase in growth had occurred by May, when the well picked plot carried a crop as large by frond count, though not as heavy by weight, as that on the control areas. Plots badly picked at the beginning of the experiment had ultimately less than half the amount of seaweed present on the control areas (Text-figs. 17 and 18).

Experiments on Gigartina

Following these preliminary results and because a high percentage of *Gigartina* was desired in the total harvest, experiments on *Gigartina* alone were set up on the



TEXT-FIG. 18

Diagrams to show the wet weight of *Chondrus* and *Gigartina* picked in May 1943 from experimental plots at Aberarth after different methods of harvesting during the previous season

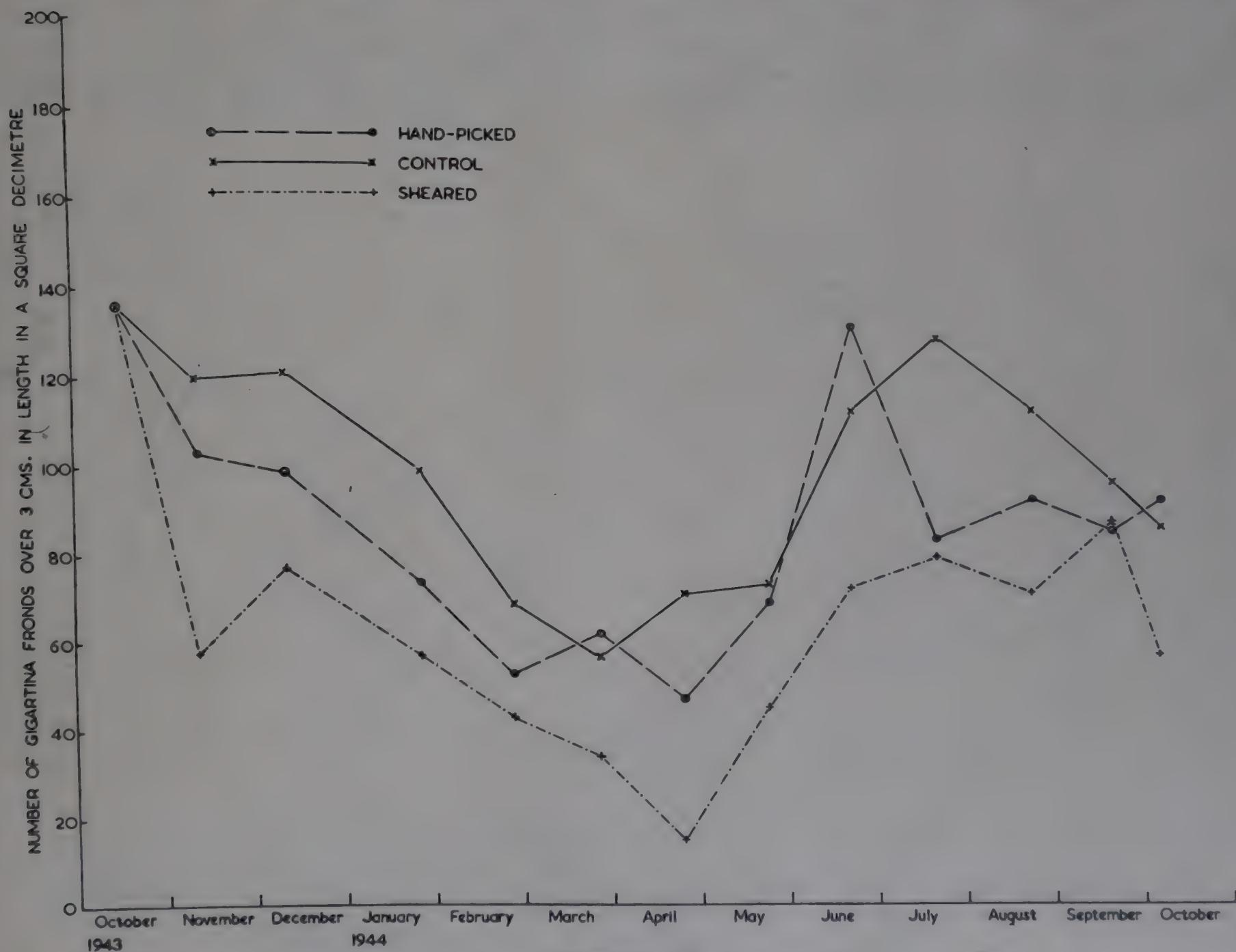
Cumbræ and in several parts of Wales. A typical experiment was carried out at Horton (Gower), where the plant grew in its optimum tidal ranges, approximately at and immediately above low water mark of spring tides. Plots were marked out by scraping a wide strip bare of all growth around each area and then painting the bared rock with ship's paint. Each plot was 0.5×1 m. and they were respectively (1) sheared, (2) hand picked and (3) left untouched as a control. All three plots had a southerly exposure. The plots were small, as it was impossible to obtain larger comparable strips, owing to the uneven weathering of the underlying rock. The experiment was carried out in a *Gigartina-Lomentaria* community where the plants were firmly attached to the rocks. There were few other species present and the *Gigartina* was fairly dense. This was to some extent comparable with the growth of the plant on the Cumbræ where similar experiments were in progress.

The results were recorded as : the number of fronds

over 3 cm. in length, the average length of thallus, and the wet weight of seaweed from one square decimetre of each plot, respectively. In this case the 'sheared' material was cut with shears immediately above the holdfasts. The 'hand picked' material was gathered as it would be by harvesters, gathering all that could conveniently be taken in the hand. The holdfasts and some of the fronds would be left in position, as some of the thalli slip through the fingers rather like wet rubber bands.

The experiment was commenced in October 1943 and the results which were recorded monthly are shown in Text-figs. 19, 20 and 21.

Text-fig. 19 shows the results of the different methods of harvesting, estimated as the number of fronds over 3 cm. in length in a square decimetre. The graph shows that in general the material decreased in quantity during winter and reached a minimum during March and April. This is because the fronds are torn away by winter gales in Gower, as they are also at Aberayron and



TEXT-FIG. 19

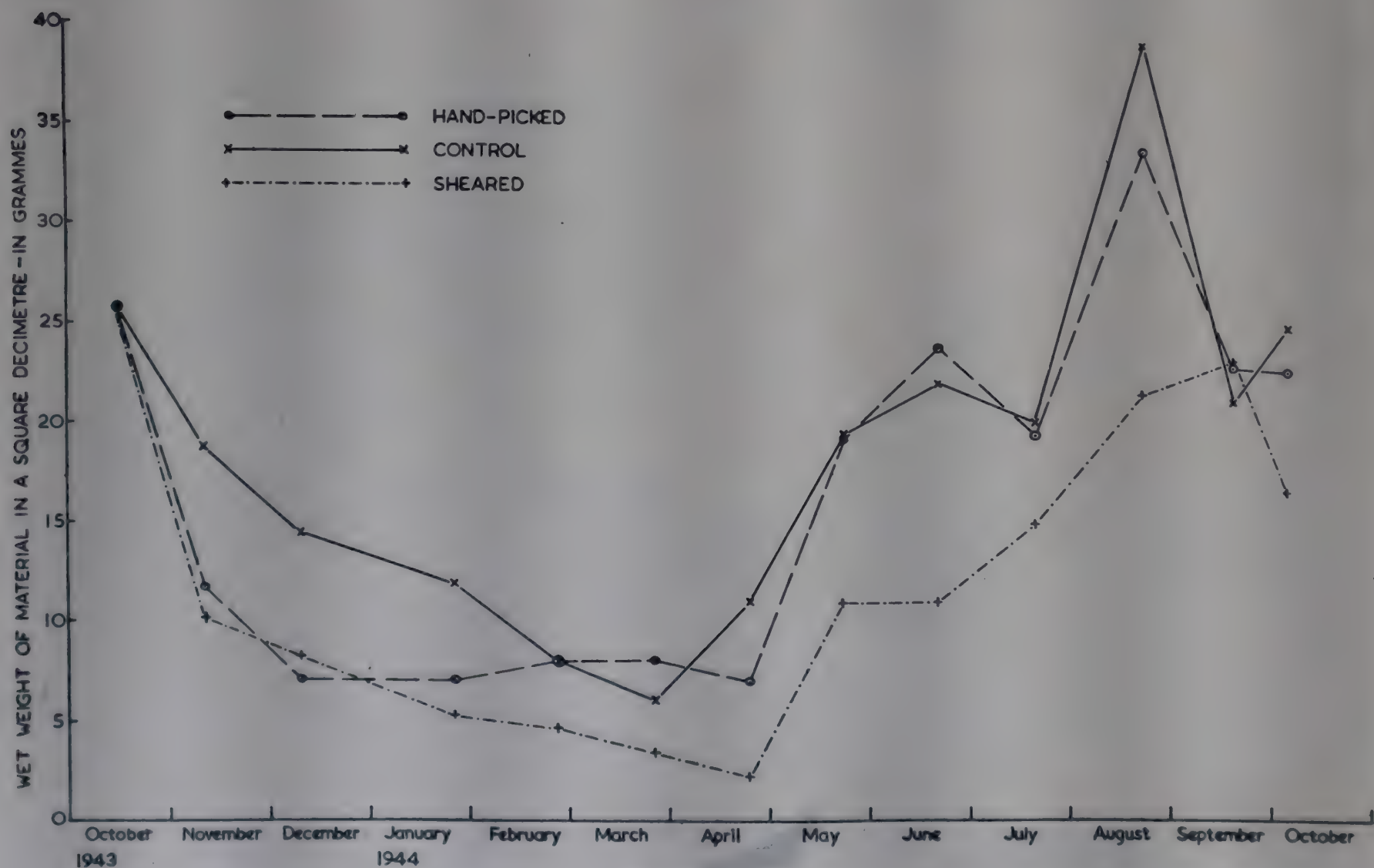
The effect of different methods of harvesting Gigartina at Horton (Gower)

I. Number of fronds over 3 cm. in length on areas of one square decimetre

on the Cumbrae. There was an increase in amount in May and June, corresponding to the very noticeable spring vegetative growth. The peak of growth was reached in July (control) and the amount of material decreased in quantity again in autumn (September, October). The sheared plot had not recovered by the ensuing season, but the hand picked plot compared favourably with the control. Weight results are given in Text-fig. 20. These also show that the material was being torn away in winter, and that new growth was well established by May. It reached its maximum in August and decreased again in autumn. This graph shows also that the hand picked plot was comparable with the control, but that the sheared plot had not recovered. The average lengths of frond obtained each month are shown in Text-fig. 21. There was a marked increase in length during May and an August maximum. The fronds were shorter in winter, the lowest figure being recorded in February (control and hand picked). After August the fronds began to be torn away and there was a decrease in the average length. The graph agrees with Text-figs. 19 and 20 in showing that a sheared plot had not recovered to the same extent as one that had been hand picked. One probable effect of shearing is that the new fronds are much more exposed to desiccation,

because they lack the cover afforded by longer thalli. Some of the old thalli remain in a hand picked plot and serve as a protection for the growing fronds. The importance of this is considerable, because work both in Wales and Scotland has established the fact that *Gigartina* plants will not develop singly but require mutual protection. In addition, shearing of the weed on the type of coast found at Horton exposes bare patches of sand between the *Gigartina* clumps and these are soon colonised by other algae. Competition with these latter may impede the growth of the *Gigartina* holdfasts and consequently the regeneration of fronds in spring will be less well marked.

When all the plots were re-examined four months after the conclusion of the experiment, the control and the hand picked plots were difficult to distinguish from each other, while the plants in the sheared plot were becoming moss-like and intruding algae were being crowded out. Some of these intruders were 'annuals' and died off; the moss-like growth of the young fronds of *Gigartina* would prevent their re-establishment in the next season. However, it would take at least two seasons at Horton before the growth on a sheared plot would be comparable to that on a hand picked one. Similar experiments were



TEXT-FIG. 20

The effect of different methods of harvesting Gigartina at Horton (Gower)
II. Wet weight of material from areas of one square decimetre

carried out on the Cumbræ,* where conditions are optimal for *Gigartina* and the sheared plot recovered more quickly than at Horton, but even so the shearing method was less desirable than hand picking.

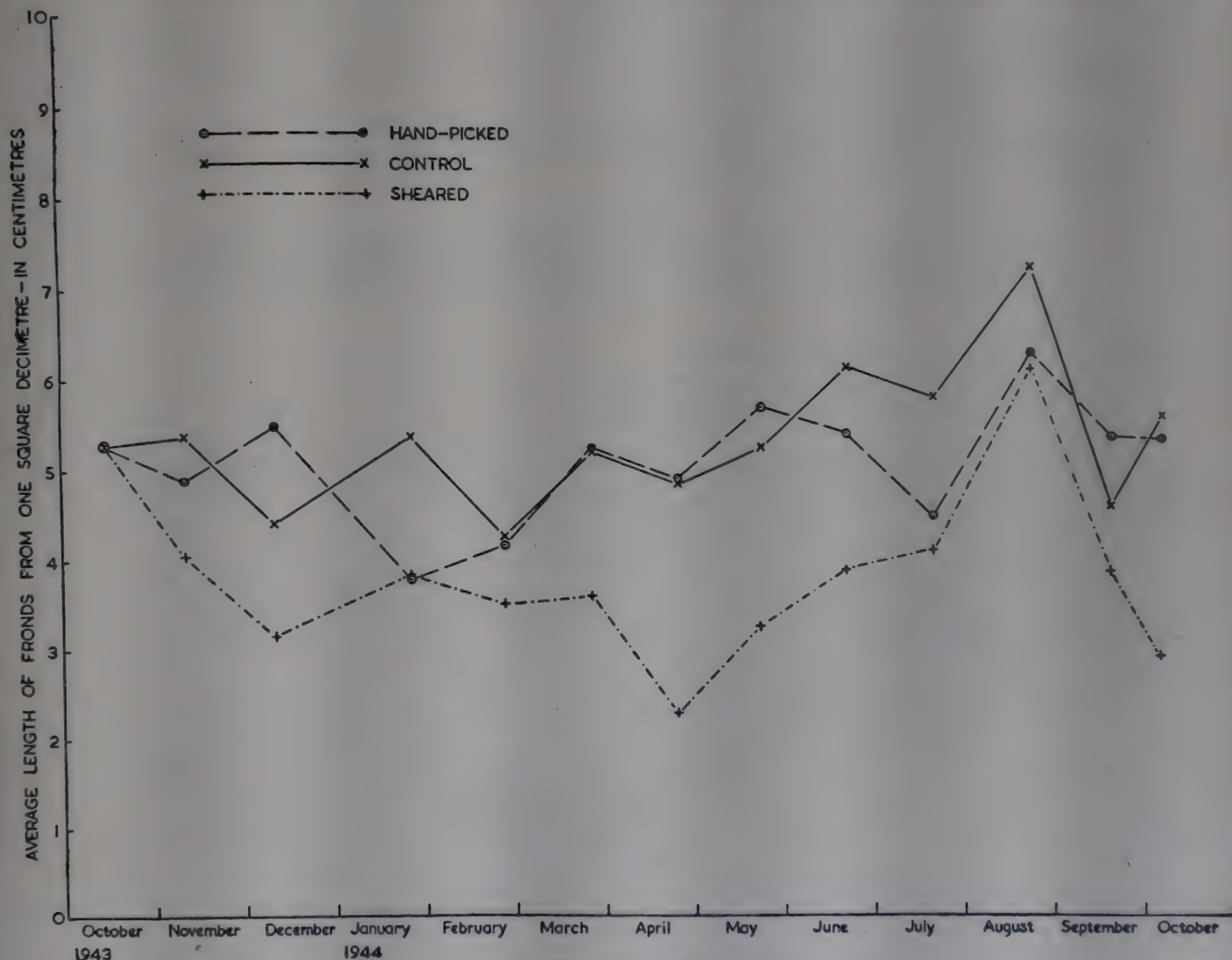
The results of all these experiments indicate that care needs to be exercised in harvesting in all areas, that hand picking is much more desirable than shearing, and that in places where the basal holdfast can be torn away with relative ease, especial care is necessary to prevent the loss of a future crop. In rocky areas where the holdfast is difficult to remove, careful hand picking does not appear to jeopardise future harvests.

Further experiments are in progress to ascertain the effect of continuous harvesting over a period of years.

2. TIME OF HARVESTING

The data from the foregoing experiments have also provided valuable information concerning the best time

of harvesting the crop. It is clear from the graphs that in no type of locality can harvesting be recommended before May, as the spring vegetative growth would be interrupted by earlier gathering; nor is it desirable after early September, when spore discharge is actively in progress. If the crop were picked in early July in areas where optimum conditions prevailed, the plants would have produced new cystocarps on regenerated fronds by September and the loss of spores would be negligible. It is a fact, moreover, that the seasonal fluctuations in the gel strength (p. 83 *et seq.*) make it undesirable to start the harvest before June. The gel strength remains high until the fronds are torn off by winter gales, but because of the time of spore discharge, and the usual occurrence of high seas at the end of September, the harvesting months were ultimately restricted to July, August and early September. By waiting until July the maximum weight is ensured in



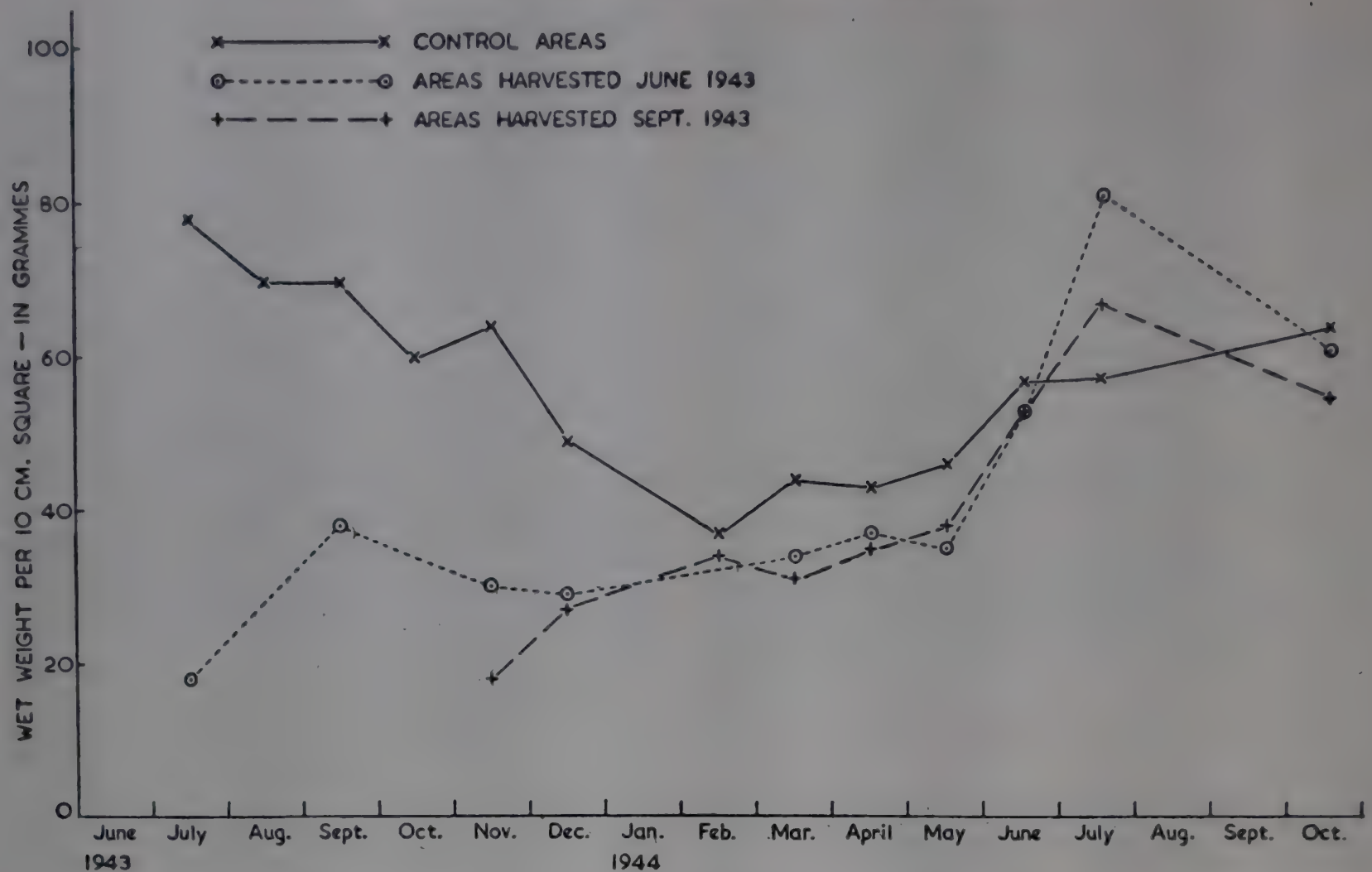
TEXT-FIG. 21

The effect of different methods of harvesting Gigartina at Horton (Gower)

III. Average length of fronds from areas of one square decimetre

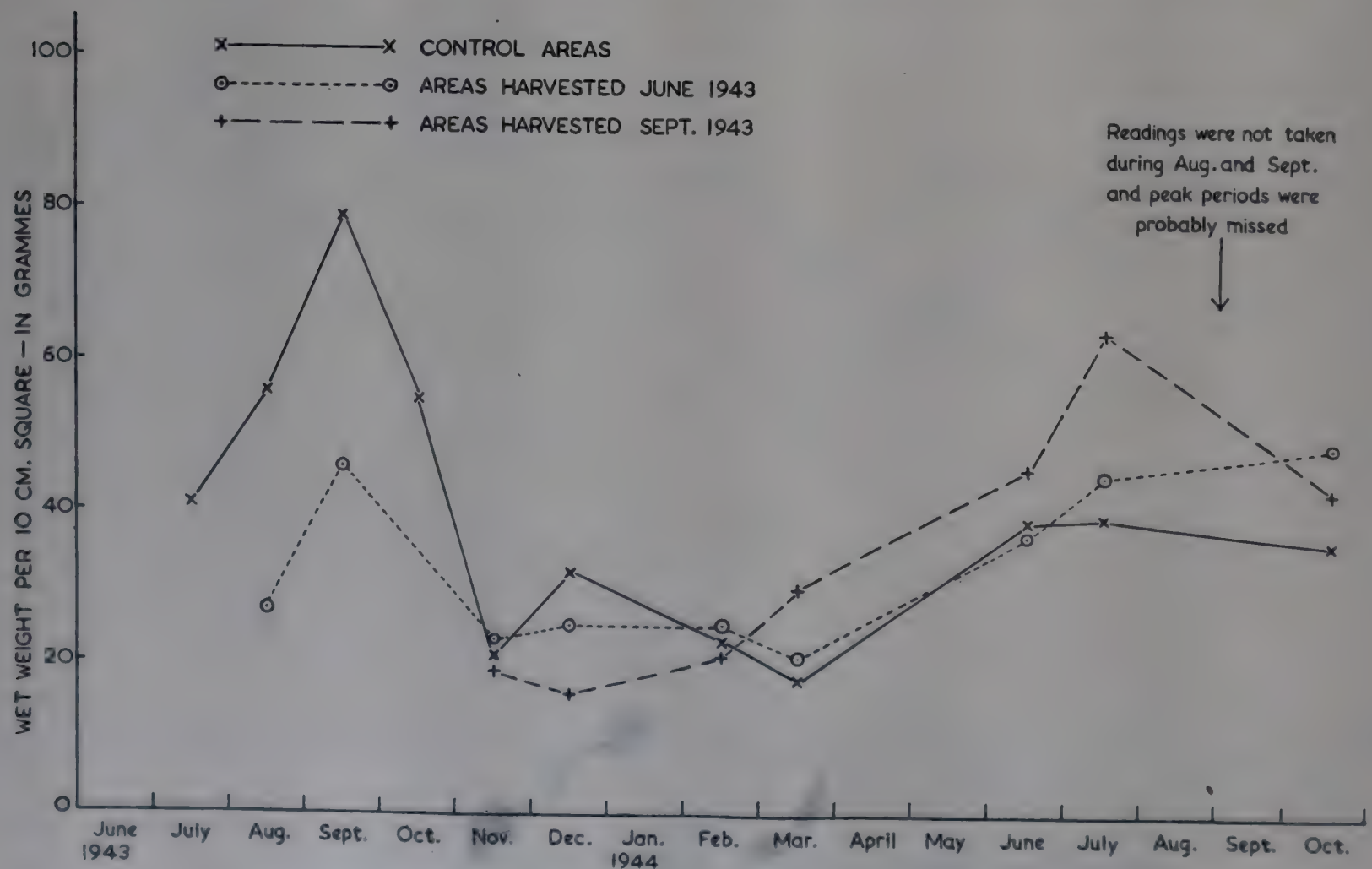
*A photograph of the experimental quadrats at Keppel Point, Cumbræ, is contained in the Ministry of Supply Permanent Record Monograph, No. 11,145. (Plate C).

A STUDY OF BRITISH SEAWEEDS



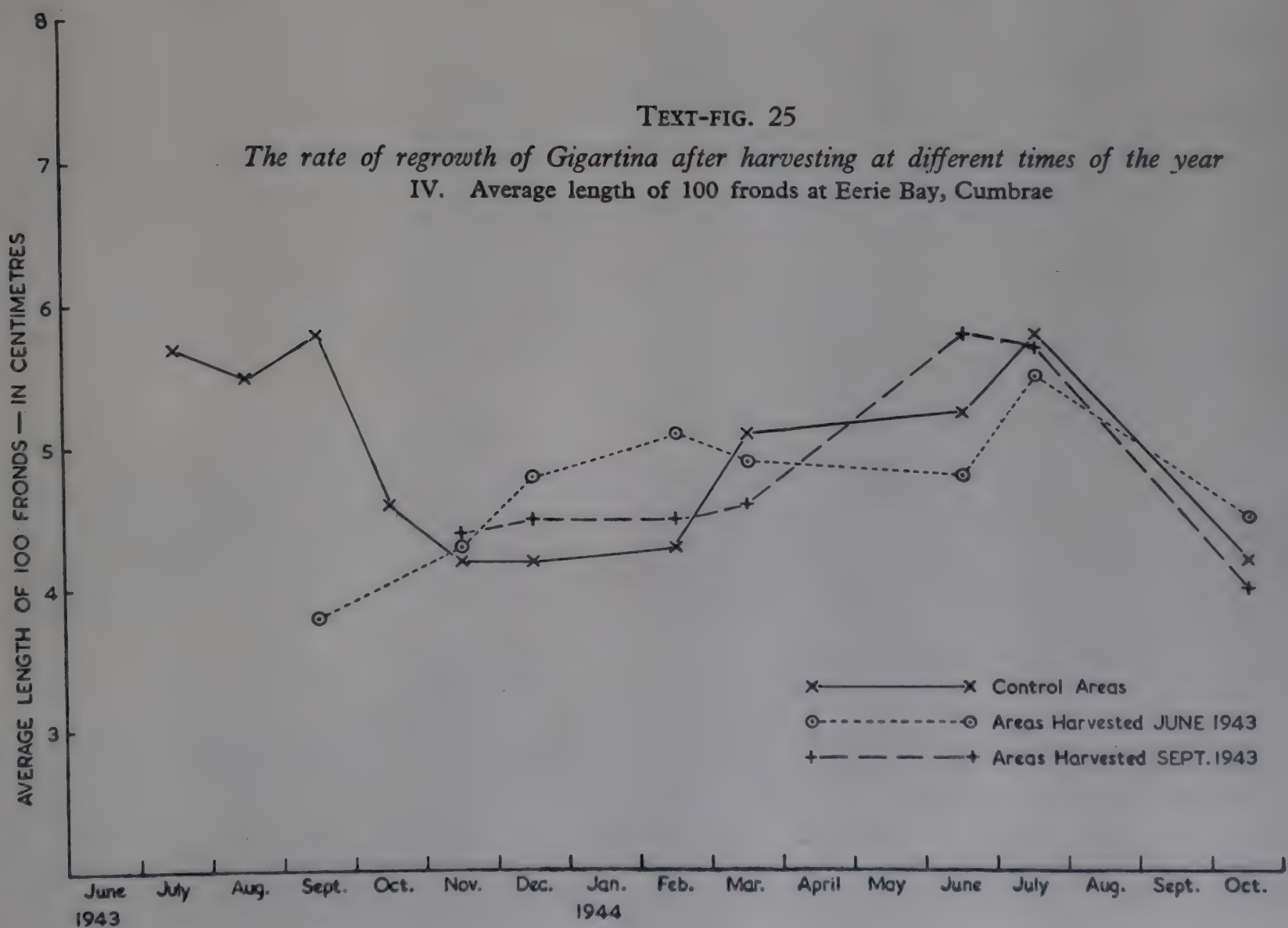
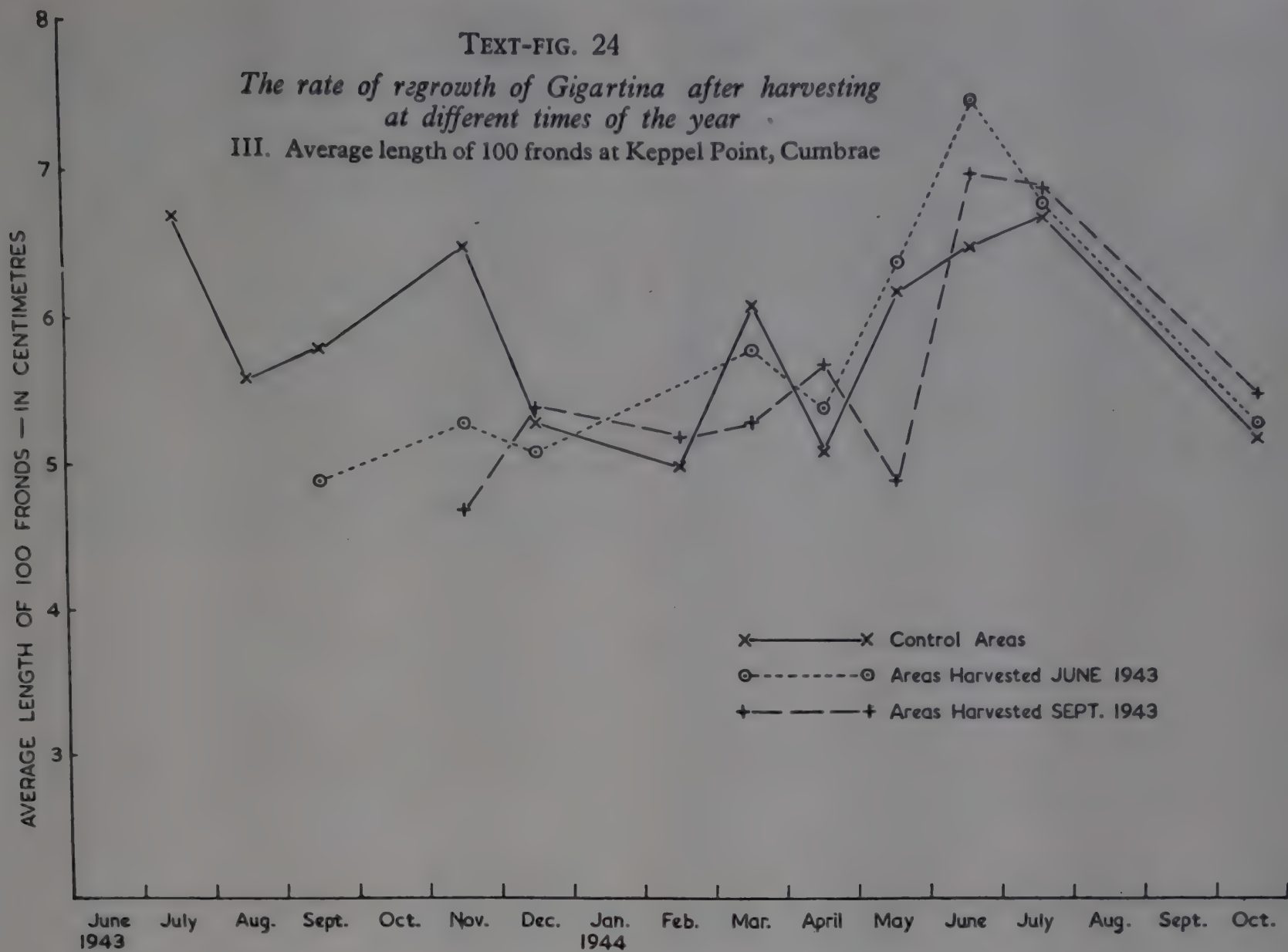
TEXT-FIG. 22

The rate of regrowth of Gigartina after harvesting at different times of the year
 I. Wet weight of material from areas of one square decimetre at Keppel Point, Cumbræ



TEXT-FIG. 23

The rate of regrowth of Gigartina after harvesting at different times of the year
 II. Wet weight of material from areas of one square decimetre at Eerie Bay, Cumbræ



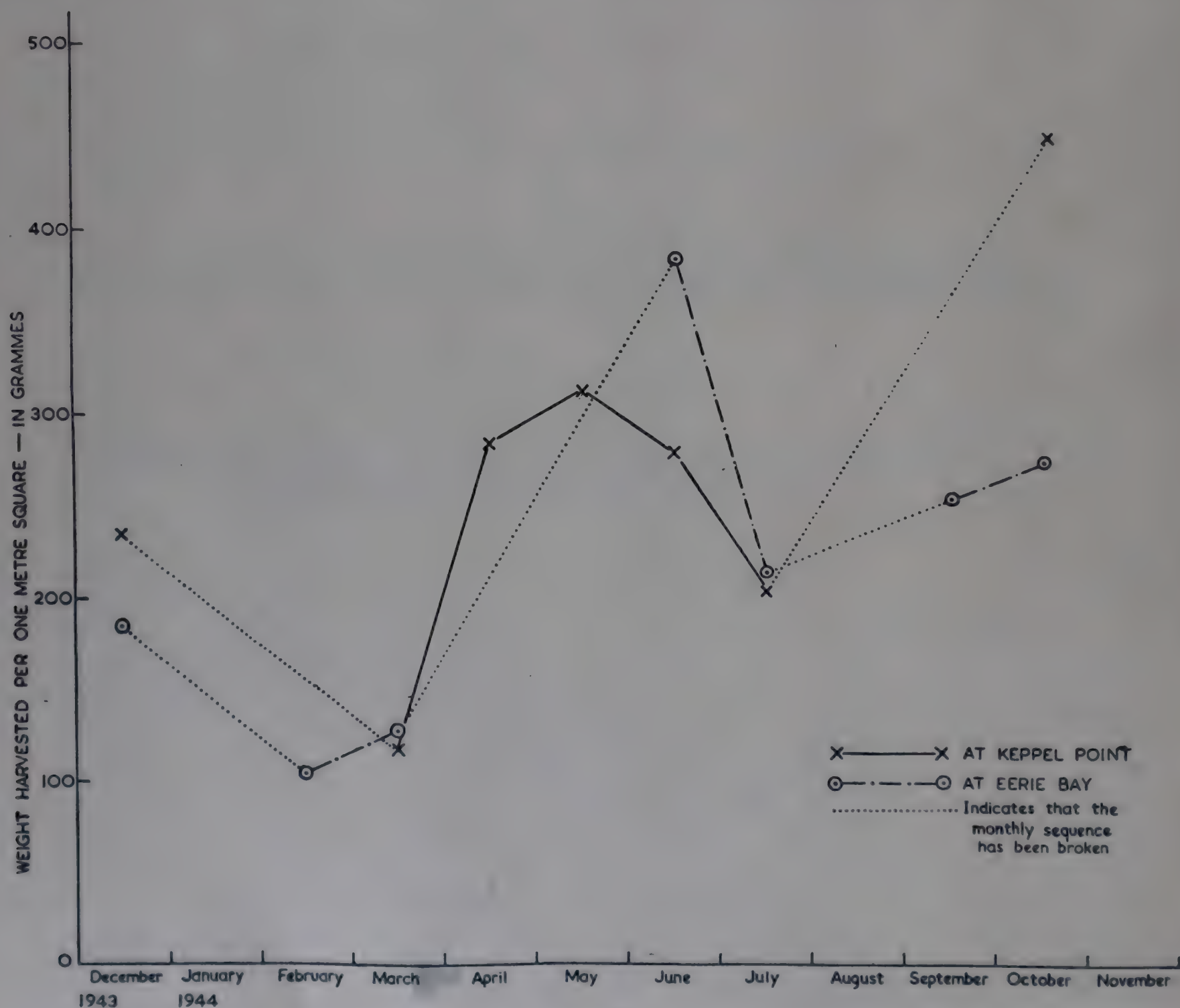
most areas. Although other agar-yielding weeds can be harvested from drift-weed (Wood, 1941), such a practice is not possible for *Gigartina*, since the gelling substance is readily lost from dead material by immersion in water.

3. EFFECT OF HARVESTING ON FUTURE YIELDS

Experiments were undertaken on the Cumbrae to ascertain whether the date of harvesting had an appreciable effect on the next year's crop. Text-figs. 22-25, from two different areas on the Cumbrae, indicate that there is little difference in that area, whether an early or late harvest is taken. Though this is true in rich areas, it has been observed in practice in Anglesey and Cornwall that the maximum harvest obtainable is later in areas from which the weed has been gathered the previous year.

4. NUMBER OF ANNUAL HARVESTS

Experiments were carried out at Horton (Gower) and on the Cumbrae, to ascertain whether it would be profitable to take a harvest from an area more than once a year. Both areas used were rich from the harvesting point of view. At Horton, a plot (0.5×1 m.) was marked out in July 1944. The material was hand picked from it on July 19th and the wet weight recorded. On September 18th 1944, it was again picked. The weight of the material was 70% of that picked in July. It was noticed that there was a marked vegetative growth in August which would account for the recovery of the crop after the first picking. It appears therefore that it would be possible to take two harvests in one season at Horton, although the total crop would be small compared with that of richer areas



TEXT-FIG. 26

The effect of harvesting Gigartina at monthly intervals from areas of one square metre at Keppel Point and Eerie Bay, Cumbrae

such as on the Cumbrae and actually it is doubtful whether such a course would be expedient.

An experiment on the Cumbrae showed the following results on plots of 1 sq. m., which were harvested three times during one season (Table 5). The figures in brackets indicate the harvests from control areas which were harvested only once.

TABLE 5

WEIGHT OF GIGARTINA WHEN PICKED THREE TIMES IN ONE SEASON

	KEPPEL POINT (WT. IN GM.)	EERIE BAY (WT. IN GM.)
Picked in March	1,246	500
Picked in June	2,102 (7,090)	863 (2,727)
Picked in September....	2,926 (5,341)	866 (1,590)

It will be observed in the controls that by September a loss of fronds owing to wave action had begun. That loss is not of course incurred with the short fronds of the picked areas. Further experiments on the Cumbrae, including an investigation of the effect of monthly gathering (Text-fig. 26), give additional support to the view that only one harvest annually is desirable. It has also been observed that areas which have been over-picked tend to have a less dense growth the following season. This allows both plant and animal intruders to make their way into the Gigartina association and introduces undesirable competition.

In view of all these results and of the fact that weed picked when young does not give the gel strength of mature weed, it seems unlikely from the point of view of agar production as a long term policy that more than one annual harvest can be taken with advantage.

It should be emphasised that in the graphs and tables the figures are really only relative and comparable within one table or graph. The amount of growth varies considerably, not only in relation to the position in the zone, but also from one rock to another and from year to year.

5. WEEDING EXPERIMENTS (i.e. removal of all seaweeds other than Gigartina)

In some localities Gigartina was observed to exist underneath the spreading thalli of the larger brown algae, near the upper limit of its normal tidal range. The Gigartina plants were poor, with few or no reproductive organs.

Experiments to determine whether the amount of Gigartina present under these conditions could be increased by weeding away the overlapping algae were carried out at Aberystwyth immediately north of the pier, at Bull Bay (Amlwch, Anglesey), and on the Cumbrae. In both Welsh localities Gigartina was growing in its usual rocky habitat near low water mark and extending also as an underflora in the *Fucus serratus* zone at

Aberystwyth and in the *Ascophyllum nodosum* zone at Bull Bay. The localities were chosen for comparison, as the precise habitat of the plant is different in the two places. At Aberystwyth, the Gigartina grows in the selected area on sand-covered shingle near low water mark and is overlapped by *F. serratus*. At Bull Bay, in the area chosen, Gigartina grows on vertical rocks under *F. serratus* and *A. nodosum*, in competition with smaller algae, in an almost closed association. The Gigartina plants were kept free from competitors throughout the experiments.

Experiment at Aberystwyth

An area of the shore 4×1 m. was weeded, the adjacent area acting as the control. The dominant alga *F. serratus* was carefully removed. In some cases it was difficult to remove the Fucus holdfasts without damaging the Gigartina, as the holdfasts of both plants were growing so closely together. The algae overlapping the sides of the plot were cleared to prevent lateral overlap. The experiment was commenced in October 1942. By February 1943 (after 5 months) the bare patches had been recolonised by other algae and young plants were visible of *Cladophora* sp., *Ulva* *Lactuca* var. *latissima*, *Rhodymenia palmata*, *Ceramium rubrum* and *Fucus serratus*.

Detailed observations in June 1943 (after 9 months) showed that there was no colonisation of the bare patches by Gigartina, but the plants already established grew larger and produced more fronds (verified by sample weight estimations and frond counts) (see also Plate II, C, 1-4). Observations in November 1943 (after 14 months) showed that the colonisation by other algae continued and that the existing Gigartina continued to grow. In spite of the fact that the plot was kept weeded for one year, no sporelings of Gigartina were visible on the bare patches at the end of that time.

Further observations in April 1944 showed a similar colonisation of bare patches by rapidly growing green algae, mainly *Enteromorpha* sp., and by August 1944 (after 22 months) the Fucoid community was again establishing itself and replacing the green algae which were the first macroscopic colonisers.

Experiment at Bull Bay, Amlwch

This experiment was also commenced in October 1942. A similar sized plot to that at Aberystwyth was weeded. It extended from the lower part of the *Ascophyllum* community into that of the *F. serratus*. Large numbers of small algae were removed from among the Gigartina plants, in addition to the larger ones that were overlapping laterally.

By March 1943 (after 5 months) the Gigartina had grown slightly, but its growth was not as rapid as at Aberystwyth (Plate II, D, 1 and 2). Numerous small algae were recolonising the bare patches and were weeded out. These were *Rhodymenia palmata*, *Plumaria elegans*, *Enteromorpha compressa*, *Lomentaria articulata*,

Cladophora sp. and *Porphyra umbilicalis*. In July 1943 (after 9 months) the colonisation of bare patches by species other than *Gigartina* had continued. The more common were *Porphyra umbilicalis*, *Fucus serratus* and *Cladophora* sp.

The *Gigartina* seemed to be unable to compete with these species. The amount of *Gigartina* in the weeded plot was calculated from the weight of a sample taken from a portion of the area and was no more than that from a control plot.

Observations made in September 1943 (after 11 months) confirmed those of July. The *Gigartina* was unable to grow with even partial success without the overlapping thalli of the Fuci and no sporelings had colonised adjacent bare patches of rock. Small plants weeded out were those of *Enteromorpha compressa*, *Fucus serratus*, *Porphyra umbilicalis* (mostly dying off), *Rhodymenia palmata*, *Corallina officinalis*, *Ascophyllum nodosum* (one small plant), and *Cladophora rupestris*. Final observations in July 1944 (after 21 months) confirmed the fact that *Gigartina* could not develop until the overlapping Fuci had regrown to act as a screen, probably against desiccation and perhaps against excessive insolation. The *Gigartina* plants on exposure became greenish in colour. The Fuci had regrown as at Aberystwyth, but they formed a 'carpet' at Bull Bay and shaded out all the algal life beneath. Very few of the species recorded as underflora during the experiment had managed to establish themselves during the year; some of them were annuals and their appearance would only be seasonal. It seems unlikely that any great increase in *Gigartina* would result from a weeding experiment of this type. This has been confirmed by later observations carried out up to February 1947.

Experiments on the Cumbrae

Weeding experiments on the Cumbrae gave similar results and indicated that weeding would not be worth the labour involved. At the top of the *Gigartina* zone the *Fucus* species are very quick growing and dominant, and it is perhaps worthy of note that *Fucus vesiculosus* has been found establishing itself in great density on weeded areas both in the predominantly *Fucus spiralis* and in the *Ascophyllum nodosum* zones. This has also been shown by David (1943) for cleared areas in the *A. nodosum* zone at Aberystwyth. Under these Phaeophyceae the *Gigartina* continues to grow only to a very moderate extent.

In the middle of the *Gigartina* zone, in rich areas where *Gigartina* forms an almost pure consociation, it becomes so densely established that it allows few intruders and several plants of *F. vesiculosus*, *F. serratus* and *Himanthalia lorea*, that appeared on certain weeded plots, later failed in the general competition. Annuals such as *Enteromorpha*, *Ulva* and *Porphyra* may be locally abundant in some years, where the association is not closed.

In the lower part of the zone the plants are never so dense and on the experimental plots on Keppel Point, Cumbrae, the chief intruders were *Himanthalia lorea*, *Ulva Lactuca* and occasionally small plants of *Laminaria digitata*. Of these, *Himanthalia* was by far the most predominant and removing it appeared to make little difference, since it soon re-appeared and was a more rapid grower than the *Gigartina*; *Himanthalia* did not however eliminate the *Gigartina* as did the Fucoids at the higher levels of the zone.

Results of experiments in Eire (Anon., 1939) also indicate that weeding in the *Gigartina* zone would not have economic value.

All the results show that in localities where poor plants of *Gigartina* occurred as an underflora to a Fucoid community, weeding out of other algae was not really profitable. The *Gigartina* already present was able to grow a little larger in some areas, but no colonisation of the bare patches took place and the increase in the total amount of *Gigartina* was not very appreciable, even near low water mark. At Bull Bay the effect was actually deleterious, since the removal of the overlapping Fuci impeded the growth of the *Gigartina*. When the *Fucus* thalli regrew, the growth was carpet-like and all underflora was excluded. The existing species, including the *Gigartina*, were shaded out. The Fucoid community also re-established itself in weeded areas at Aberystwyth, but because of the nature of the substratum (sandy shingle), a carpet growth of Fuci was impossible and the underflora was not destroyed as at Bull Bay. It appears therefore that when the Fuci and *Gigartina* occur together at the upper limits of the latter, light and desiccation are probably limiting factors. The presence of the Fuci, provided the cover is not too dense, allows poor plants of *Gigartina* with few cystocarps to exist, since the protecting Fucoid thalli prevent excessive desiccation during low tide. In most instances, however, it is clear that *Gigartina* plants growing under the Fuci are really outside their true zone and no amount of weeding will produce a crop in such a habitat.

6. EXPERIMENTS ON COLONISATION BY SPORELINGS

Detailed observations were made to determine whether sporelings would colonise bare patches of rock on the shore, if such occurred within the tidal range of *Gigartina*. This had an obvious importance, because the result would help to elucidate the life-history of the plant and indicate whether cultivation on artificial substrata placed in the sea would be commercially practicable. Experiments were carried out in different places and under varying conditions.

At Horton (Gower), in one series of experiments, three plots 0.5×1 m. were cleared in July 1943 in the *Gigartina*-*Lomentaria* community. The rock surface was sterilised by using a blow lamp and then washing with a 2% solution of mercuric chloride. This not only

sterilised the surface, but also removed the comparatively loose and partially weathered fragments as well as clearing the sand and debris from the rock surface. The experiment was commenced in July, in the hope that the surface would have recovered from any chemical effects of the mercuric chloride before the spores of *Gigartina* were shed in the autumn.

The plots were at different distances from low water mark, and sloped in different directions, but they were all exposed surfaces on which *Gigartina* was growing before clearing. Visits were made at regular monthly intervals and the macroscopic recolonisation recorded.

These periodic observations showed that the first macroscopic colonisers were chiefly the green algae, *Ulva Lactuca* var. *latissima* and *Enteromorpha compressa*, with some red algae such as *Porphyra umbilicalis* and *Ceramium rubrum*.

After six months some other species were represented, *Laurencia pinnatifida*, *Ceramium flabelligerum*, *Fucus* sp. and *Callithamnion Hookeri*, although all the plots were still mainly green in colour. After seven months, in February 1944, a few small plants of *Gigartina* (0.5–1.0 cm. in length) were recorded in the plot nearest to low water mark. They were first recorded in the other two plots in March (after eight months) and in April (after nine months) respectively. As the year progressed, some of the first colonisers were temporarily replaced as they died down and some 'ephemeral' species made their appearance, e.g. *Enteromorpha Linza*, in July and August. By February 1945 (19 months after clearing) the *Gigartina* community was re-establishing itself near low water mark, in competition with *Fucus serratus* and *Laurencia*. In the other two plots this was also occurring, but more slowly.

In a second series at Horton, a small plot (0.25 × 0.25 m.) was cleared each month and sterilised by the method already described. The experiment was designed to ascertain whether the month in which the substratum was cleared affected the subsequent rate of colonisation by *Gigartina*. The results, on the whole, confirmed those obtained in the first series of experiments. The preliminary macroscopic colonisers were, in each case, the green algae and by February of the following year some *Gigartina* plants were recorded in plots cleared in each of the months March to August of the previous year. Plots cleared during and after September did not begin to be colonised until later than February. It has since been ascertained experimentally that mercuric chloride has an inhibiting effect for many months on the establishment of some colonising algae, even when repeatedly washed by subsequent tides. It has also been observed that *Gigartina* is never the primary coloniser, but that other growths appear first. In the case of the experiment under review, it is evident that the areas cleared after September would not have had time to recover from the effects of the mercuric chloride treatment while there were

still spores of green algae available for recolonisation.

A site cleared on the Cumbrae by *scraping* (without chemical sterilisation) in June was colonised by *Ulva Lactuca* and *Enteromorpha compressa* by mid-August, and these plants had mostly disappeared by December, when *Gigartina* fronds were 0.5–1 cm. in length. In the following June (i.e. 12 months after clearing) both in frond length and in weight per unit area the plot could hardly be distinguished from the surrounding control areas, though the cleared area on closer inspection could be seen to be less densely covered (see Plate V, A and B).

Another set of experiments was carried out concurrently on the Cumbrae in October 1944, and was designed to ascertain whether the rate of colonisation of bare patches of cleared rock in the *Gigartina* zone would be increased if spores were shed on to them artificially. The results might also have given some indication of whether the spores shed in autumn grew into cystocarpic plants. Control and experimental areas (0.5 × 1 m.) were cleared, but unfortunately the plots were sterilised with 2% mercuric chloride, because at that time its deleterious effect had not been ascertained. The plots were re-examined in March 1945, after five months. Both the experimental plots and the controls were covered completely with a growth of *Enteromorpha Linza*, with some *Porphyra umbilicalis* and a few plants of *Phyllitis Fascia*. Although no large *Gigartina* plants had developed on these plots, there were numerous small plants 2.5 mm. in length forming a carpet on small rough debris-covered surfaces which had been produced artificially in the middle of the surrounding *Gigartina* community. Sections of the holdfasts showed that these were not regenerating fronds but new plants. The experiment was repeated in the same locality in 1946 but without applying mercuric chloride and the results are shown in Plate VI, A, B and C.

In spite of the possible deleterious effects of the sterilising agents, the result of the experiments indicates that *Gigartina* spores are unable to grow on a sterilised rock surface unless some primary colonisation by diatoms and green algae has taken place. It is also evident that the time when clearing takes place is of importance in relation to the rate of recolonisation by *Gigartina*. This is equally true in the Gower Peninsula where the plant occurs mainly on isolated rocks and boulders near low water mark, and on the Cumbrae where it forms an almost continuous cover over extensive rock ledges. The fact that the sporelings of *Ulva* and *Enteromorpha*, which cover cleared areas with vigorous growth in the spring, appear to be a necessary preliminary to recolonisation by *Gigartina*, influences the season when such recolonisation can take place. One factor may be that the green algae afford protection from desiccation until the *Gigartina* plants are large enough to provide mutual protection. The rate of complete re-growth cannot be compared in all of these experiments because the effect of mercuric chloride is now known to be



detrimental to algal colonisation for some considerable time after its application and the length of that time may vary on different substrata.

Attempts were also made at Aberystwyth and on the Cumbrae to grow *Gigartina* spores on glass and 'perspex' surfaces on carriers in the sea, in open-air aquaria, and in the laboratory. In no case was successful settlement obtained.

It is clear from the results of all the recolonisation experiments that the spores of *Gigartina* are unable to grow and develop on bare rock surfaces, even under otherwise optimum conditions. Some primary algal colonisation is necessary and then, in the shelter afforded by these algae, the spores will grow. This may be because colonies of *Gigartina*, even in the very earliest stages of development, tend to retain water in a sponge-like manner, and are unable to withstand complete desiccation. This is equally true of the adult stages, as was shown earlier (p. 50). The stages in the colonisation of a cleared area in the *Gigartina* zone appear to be first, a covering of diatoms; this is followed in succession by the development of green and some-

times of brown algae; later still *Gigartina* begins to appear. Growth continues until a stage is reached in which *Gigartina* is competing for dominance with *Fucus serratus* and *Laurencia*, as at Horton (Gower). There is no doubt from general observation that the competition continues until *Gigartina* is established, either as a dominant constituent of the community, or as a complete coloniser, dependent on other ecological factors. The spores shed on to clean slides and placed in the sea were probably unable to persist, though subsequently the same early stages of colonisation by diatoms and other algae were observed on the slides, as on the rock surfaces.

The experiments on spore development have recently been modified by H. T. Powell and are being continued with much more promising results.* The results of the experiments with spores are important from the commercial point of view, because it is clear that if the artificial culture of *Gigartina* were contemplated, there would be considerable practical difficulties involved, as compared with the methods used by the Japanese and others for *Porphyra* and by the Japanese for *Gracilaria*.

(B) *CHONDRUS CRISPUS* (L.) STACKH.

TAXONOMY

It has already been stated (p. 7) that the study of the ecology of *Chondrus* was not continued after it had been ascertained that the plant would constitute only about 5% of the total carrageen harvest. Thomas (1938) has elucidated much of the ecology of the plant but this paper became available only after the present study of *Chondrus* had been confined to the investigation of seasonal fluctuations in gel strength. The earlier observations which were made, however, will be recorded here, together with the experimental results that have been obtained.

The genus *Chondrus* (from the Greek 'chondros', meaning cartilage) belongs to the Gigartinaceae. The species *Chondrus crispus* (L.) Stackh. exhibits even greater polymorphism than *Gigartina stellata* Batt. (see Colour Plates I and II), and a large number of varieties have been distinguished by various authors. Turner (1808-1819) described and listed ten varieties; Lamouroux (1813) figured a total of thirty-five. Harvey however, in his *Phycologia Britannica* (1846-51) merely figured and described what he called "two of the most opposite forms of the plant" (Plate LXIII), as he considered it almost impossible to elucidate its polymorphism. One of the extreme forms he describes is found growing near low water mark in situations exposed to the "full dash of the open sea." It is a narrow cartilaginous form of the plant distinguished by the regular dichotomy of its branching. The apices of

the branches are rounded. The other extreme form is found in estuaries where fresh water mingles with the sea, and where mud and sand are common. This plant is broad with wedge-shaped thallus apices. It is more membranaceous in texture than the cartilaginous form and has bifid apical segments. Batters (1902) lists nine of Turner's varieties but omits Turner's var. *geniculatus*, which he does not appear to regard as a distinct variety; Newton (1931) follows Batters' classification. Thomas (1938) describes 22 forms of the plant.

Chondrus crispus has a relatively wide zonal range on the shore, some forms occurring in the littoral and some in the sub-littoral belt. The sub-littoral forms, which are cartilaginous with branches often spread out in a fan-like manner in one plane, vary much less than the littoral forms.

The chief forms of the plant found in Cardigan Bay (Wales) are illustrated in Plates IX and X. Plate IX shows a form similar to the extreme type described by Harvey as occurring near low water mark; it would appear to be the var. *filiformis* described by Turner as "frond cartilaginous, sub-cylindrical; branches nearly linear; apices long and acuminate". A1 and A2, in Plate X, are forms found growing in the sub-littoral zone at Aberayron. They resemble var. *aequalis* Turn. which is described as "frond cartilaginous, thick; all the branches equal and linear, the extreme segments obtuse." The plant figured here in Plate X, A2, is

*Prepared sandstone blocks fixed to 'perspex' slides are now being used successfully as a substratum, and it is hoped that the development of the adult plant from the disc-sporeling will be observed on these surfaces during the spring of 1948.

unusually broad and much branched. B1 and B2, in Plate X, show plants found in pools in the mid-tidal zone, both on the rocky coast at Aberystwyth and on the shingle beach at Aberayron. B1 appears to be the var. *stellatus* of Turner, described by him as "frond sub-membranaceous, . . . with numerous shortish laciniae," while B2 is believed to be the type species. This is described as having a cartilaginous frond, "flat, nerveless, dichotomous, entire at the margins, curled, segments subcuneiform, the uppermost narrowest." The thallus texture varies however and is often membranaceous. Both B1 and B2 are often iridescent, a phenomenon which may perhaps be correlated with the strong light incident in the upper part of the mid-littoral belt. Plate X, C, illustrates the type of thallus found near high water mark of neap tides on the shingle at Aberarth. It is probably a form of the type species which has become dwarfed under conditions of low salinity (Rosenvinge, 1931). The plants on Plate X, D, are the 'ephemerals' found in summer in the rock pools near high water mark at Aberystwyth. These plants also do not appear to be distinct varieties but small ephemeral forms of the type species (Plate X, B2), which do not develop further; they are destroyed from September onwards by the rough seas of autumn. Intergrades of all kinds are common between B1, B2, C and D on

Plate X, but although there are intermediates elsewhere between those shown in Plate IX and Plate X, A1 and A2, there are no intergrades found in Cardigan Bay between these and any other of the varieties described in this paper. It would appear therefore that those plants which grow in the sub-littoral zone are distinct from the plants growing elsewhere on the shore in their size, their method of branching, the linear form of the thallus and its cartilaginous texture.

The harvest of *Gigartina* and *Chondrus* collected in the 1945 season from Devon, Cornwall and Anglesey, was examined at the agar factory and it was found that the plants of *Chondrus* that had been collected most commonly were, on the whole, similar to those illustrated in Plate X, B1 and B2, which are believed to be those of var. *stellatus* Turn. and of the type species, respectively. It had been observed previously that these were the most common in the littoral region of Cardigan Bay and observations in that particular area were therefore mainly upon them. The plants found in the sub-littoral zone, var. *aequalis* Turn. and var. *filiformis* Turn., may however occur elsewhere in large quantity and consequently observations were made on them whenever opportunity arose. Observations and experimental work on the Gower coast relate to what is believed to be the type species.

ANATOMY AND REPRODUCTION

The plant is attached to its substratum by means of a disc-like holdfast from which the erect dichotomously branched fronds arise. The disc is not as firmly attached as it is in the case of *Gigartina*. The detailed anatomy of the disc has been described by Darbishire (1902). He states that it forms a flat plate of tissue, from which the upright shoots arise. He describes two types of cells, attachment cells of varying shape which anchor it to the substratum, and very regularly arranged rows of almost cubical cells which make up the greater mass of the holdfast. He figures the holdfast in section, showing these two types of tissue covered by a protective layer. In the illustration there are no layers of growth comparable to those found in the holdfast of *Gigartina*, which have been discussed earlier in this report as probably delimiting a season's growth. Darbishire, in another section of his memoir (p. 34), states that *Chondrus* is a perennial plant but he does not refer to any consequent layering or stratification of the holdfast. Holdfasts in the material from Gower, however, showed 2 or 3 seasonal layers of growth, and Rosenvinge (1931) mentions an irregular stratification in older attachment organs in the material found in Danish waters. Observations on the holdfasts of plants occurring in the mid-littoral belt in Cardigan Bay showed that they were mainly one multicellular layer in thickness but those of the plants in deeper water showed the stratifications as observed on the Gower coast, and also by Rosenvinge (*loc. cit.*).

The anatomy of the erect shoot has been described several times (Darbishire 1902, Kylin 1923, Rosenvinge 1931). The medulla is formed of elongated conducting cells arranged in longitudinal rows, 7-16 μ in diameter, connected by lateral pits and also by pits in the end walls. The cells of the outer longitudinal cell rows are much shorter than the inner ones and pass gradually into the cortical layer. This latter consists of branched, outwardly directed cell rows connected by pits. The inner cortical cells have a storage function, the outer ones are assimilatory. Thus the thallus conforms to Oltmanns' 'fountain' type (Oltmanns, 1922). According to Darbishire (*loc. cit.*) there is only one plastid in each cell, forming a lining in the outer assimilatory cells and divided into branched strands in the inner storage cells. Hyaline hairs on the thallus have been described by Rosenvinge (1931).

Observations on the coasts of Gower and Cardigan Bay have established the fact that regeneration takes place from the basal holdfast as well as from the surface and margin of a cut or broken thallus. Old fronds sometimes break away from the holdfast at the base of the erect portion and new ones arise, so that shoots of varying age and old scars may be observed on one holdfast.

The vegetative growth period observed in *Chondrus* was not as marked as that described for *Gigartina*, although observations suggested that growth occurred mainly in spring and ceased towards the end of summer.

This agrees with Rosenvinge's (1931) records for the growth in Danish waters. The new growth of the thallus was pink in colour, although it was not in such marked contrast to the deeper colour of the older thallus as in *Gigartina*. The limit of a season's growth was best seen in the cartilaginous type of thallus found in the sub-littoral zone. The new growth was distinguished by a difference in colour and texture and by being free from epiphytes, which often covered the older basal parts of the thallus completely. Rosenvinge (1931) described and figured three year old plants found growing near low water mark, thickly covered with epiphytes. He stated that in the first year the shoots branched dichotomously once or twice, in the second year subsidiary branches were formed, while in the third year there was only a growth of 1 cm. at the tips of the branches.

Observations on the plants found in the intertidal pools at Aberayron showed that most of the thalli were only of one season's duration, and the anatomy of the holdfast, which has already been described, confirmed the opinion that most of these plants were 'annuals' or 'ephemerals'. The large numbers of young plants found growing in the pools confirmed this. Their occurrence would be expected if the thalli were short lived and were continually being replaced by new plants which had grown from spores. The plants examined from the sub-littoral zone however were often 2-3 years old. After the third year it appears that the plants tend to be torn away from the rocks by rough seas, especially in November when these plants form a large percentage of the *Chondrus* in the drift weed, and a considerable proportion of the total drift. This latter phenomenon was especially striking during October gales at Pwllheli, North Wales, and the plants were mainly var. *stellatus*.

There is some evidence therefore that the longevity of *Chondrus* plants varies according to their position on the shore. It appears that in Cardigan Bay in some of the pools in the intertidal zone *Chondrus* may behave either as an annual or as an ephemeral, but in the sub-littoral zone it is usually a perennial. It has already been stated that the cartilaginous forms are rarer in the areas studied and also their sub-littoral habitat makes them of little value for shore collecting, so that in considering the problem of harvesting, it may be that most of the plants concerned are annuals. This is borne out by the fact that an area carrying a heavy crop of *Chondrus* in one year may not do so in a subsequent year. This will be referred to again when the method of harvesting is being discussed.

The plant is a diplobiont, and the three kinds of reproductive organs are borne on separate individuals. In the life-cycle asexual plants (tetrasporic) alternate with the sexual ones (cystocarpic and spermatangial). The spermatangial plants are distinguished by whitish-pink fruiting patches on the upper parts of the thallus. The cystocarpic pustules originate within the substance of the thallus, usually towards the tips of the branches.

They are often distinguishable from the tetrasporic sori as they tend to be concave on one side and to protrude from the surface of the thallus on the other. The tetrasporic sori on the diploid thallus originate in a similar position to the cystocarpic pustules on the haploid plant but, unlike the latter, they are often linear in shape, or they may occur in confluent groups. Both types of sori are easily distinguished in the young stage as they are deeper red in colour than the thallus itself.

Spermatia have been described by Buffham (1896), Darbishire (1902) and Grubb (1925). The first two authors recorded mature spermatangial plants in September and October; Grubb observed them in the spring, and she suggested two seasons of spermatial production. Spermatangial plants have been found in the present investigation to be much less frequent than either female or tetrasporic individuals, but those which have been seen were observed in winter. Grubb (1925) describes the development of "antheridial mother-cells" from outermost cortical cells, each mother cell giving rise to two "antheridia".

Schmitz (1883), Darbishire (1902) and Kylin (1923) have described the procarp, which is formed of a three-celled carpogonial branch borne on an auxiliary cell. After fertilisation the carpogonium fuses with the auxiliary cell which then gives off sporogenous filaments. These penetrate between the ordinary vegetative cells and form gonimoblast tissue which produces numerous carpospores. The ripe cystocarp contains groups of carpospores separated by shrunken hyphae.

Tetrasporangia arise in the branched cell rows produced by the cells of the medulla (Rosenvinge, 1931), either terminally or in an intercalary position. They are cruciately divided, the first wall being transverse.

The carpospores and tetraspores are shed by the disintegration of the thallus tissue covering the pustules. After the spores have been shed, holes can be observed in the thallus. The weakened thallus may subsequently be torn away by rough seas or, in more sheltered positions, it may disintegrate slowly.

Rosenvinge (1931) states that fructification occurs during the greater part of the year on Danish coasts. As this was a matter of considerable importance from the harvesting point of view, records of fruiting periods of the type species in the intertidal zone in Cardigan Bay have been carefully kept by examining 500 plants each month. These records show that both tetrasporic and cystocarpic plants occur in late autumn and winter, though tetrasporic predominate in winter and cystocarpic in summer. Very few spermatangial plants have been recorded and those which were observed occurred in winter.

The fruiting records obtained for the sub-littoral variety of *Chondrus* were very scanty owing to its inaccessibility. There was no record of spermatangial plants. Tetrasporic plants were rarely recorded, but cystocarpic plants were very frequent in the winter months.

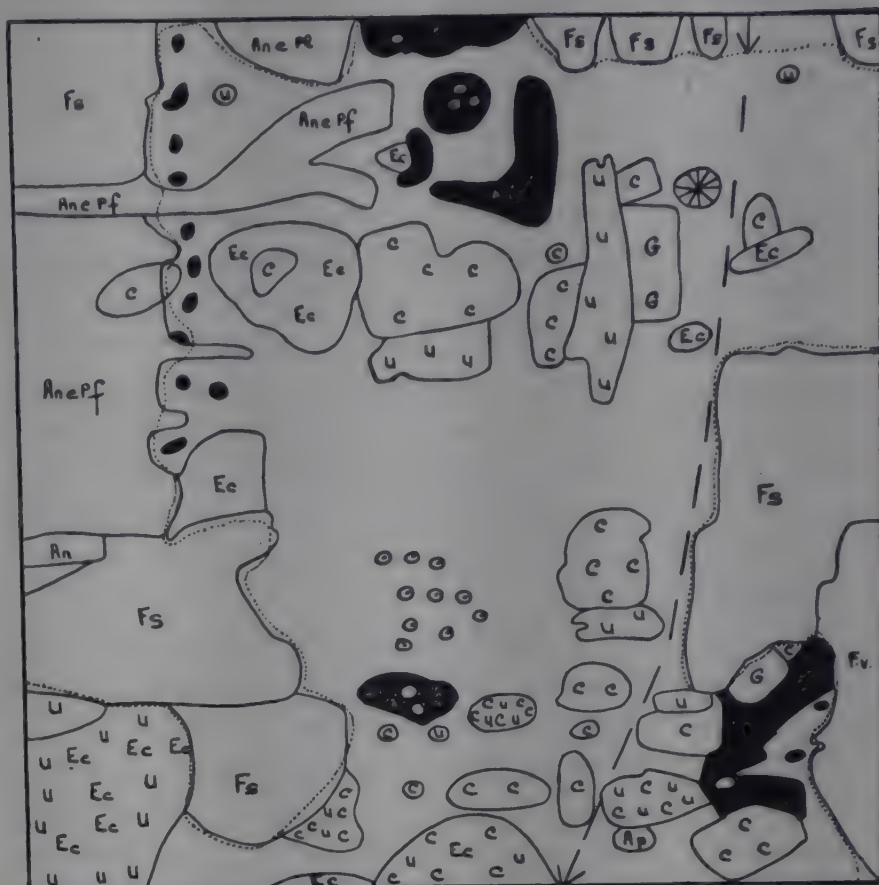
ECOLOGICAL NOTES, MAINLY ON SOME LITTORAL FORMS

Chondrus is not usually found in the littoral zone on very exposed and storm-beaten shores. Its habitat would be better described as in semi-exposed or sheltered localities. The plant occurs either in tufts or singly, but it has not been found forming closed communities, as so often happens with *Gigartina*, when the latter is growing under optimum conditions, as for instance on the Cumbrae.

Gibb (1938) lists *Chondrus crispus* as occurring in the following zones at Castletown Bay (Isle of Man): as an undergrowth in the *Ascophyllum*, the *Fucus serratus*, the *Himanthalia*, and the *Laminaria digitata* communities; forming a small proportion of the vegetation in the *Laurencia-Cladophora-Rhodochorton*, and the *Enteromorpha-Cladophora-Chordaria* communities; and occurring in intertidal 'coralline' pools and in sublittoral sand-pools. On the Isle of Cumbrae, Gibb (1939) records *Chondrus* as an undergrowth in the *Ascophyllum*, the *Fucus serratus*, and the *Laminaria* communities; forming a part of the *Laurencia* community; and occurring in intertidal 'coralline' pools and sand-pools.

Some ecological observations have been made on the coasts of Cardigan Bay and the Gower Peninsula. The portion of Cardigan Bay selected for observations was that between Aberystwyth and Cardigan. A detailed study of the distribution of *Chondrus* in the part of this area from Morfa Mawr (Llanon) to Newquay* (Cards.) shows that the plant is found mainly north of the river mouths, where the influence of the fresh water is strongest, as the south-west wind and currents tend to deflect the water northwards (see also p. 35). The correlation of the distribution with the fresh water is not, however, as sharply defined as in the case of *Gigartina*.

The *Chondrus* grows mainly in rock pools, from the mid-littoral part of the shore to low water mark of spring tides, especially if the pools are well aerated by water running through them at low tide. Such pools may often occur in the *Ascophyllum* community and in some instances fresh water flows continually through the pools during low tide. The plants found in these littoral pools are the type species and the var. *stellatus* Turn. Text-fig. 27 (see key on p. 56) is a chart quadrat showing the actual distribution of *Chondrus* in such an intertidal pool at Aberystwyth. The direction of the flow of water through the pool is indicated by the arrows and by the broken line. The area was mapped at low water of a spring tide and it should be noticed that, although the *Fucus serratus* at the side of the pool is exposed, the *Chondrus* inside the pool (delimited by the dotted lines) is always submerged. This occurrence of *Chondrus* in deep pools has often been observed elsewhere. The plant also occurs in the



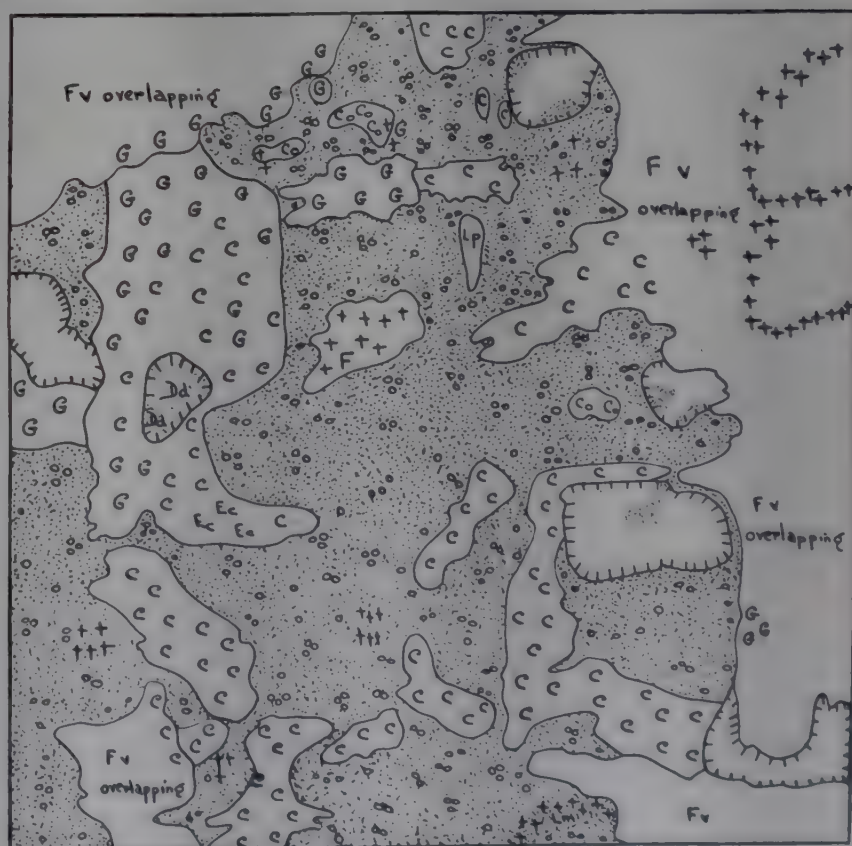
TEXT-FIG. 27

Chart quadrat to show the distribution of *Chondrus crispus* (L.) Stackh. in a rock pool at Aberystwyth (June 9th 1944). The limit of the pool is shown by dotted lines and the direction of flow of the water running through the pool is indicated by the arrows and the broken line

Scale 1 : 12

Aspect: West

Community: *Fucus serratus*



TEXT-FIG. 28

Chart quadrat to show the distribution of *Chondrus crispus* (L.) Stackh. in the mid-littoral zone of the shingle beach at Aberayron (September 1942)

Scale 1 : 12

Aspect: West

Community: *Fucus vesiculosus*

Type: Open

*Detailed distribution maps of this area are contained in the Ministry of Supply Permanent Record Monograph, No. 11,145. (Maps A and B).

Fucus vesiculosus community on the shingle beach at Aberayron where the plants are rarely dry, owing to fresh water continually seeping across the shore to the sea (see p. 35). A similar condition has been observed on the south coast of Anglesey.

At Aberayron, *Gigartina* is mixed with the *Chondrus* in parts of the area and large numbers of small plants of these two species are growing between the pebbles of the shingle (Text-fig. 28). This unstable substratum does not support a dense algal growth and the community remains open. In harvesting *Chondrus* from such a locality it would be very easy to tear away whole plants and so spoil the area for subsequent harvesting. It would also be deleterious to disturb the only partially stable shingle, on which the *Chondrus* grows (see also p. 59).

Chondrus may extend into the sub-littoral belt as it does on the shore north of the river Drowy, north of the river Aeron at Aberayron and north of Morfa Mawr. The varieties found have been var. *filiformis* Turn. and var. *aequalis* Turn. They often form an almost pure community. They may also occur as co-dominants with *Fucus serratus* in exposed positions in Cardigan Bay. In the sub-littoral situations the plants are usually constantly submerged, but they may also occur on a zone of the shore which is exposed once or twice a year at extreme low water of equinoctial spring tides.

In Cardigan Bay therefore, *Chondrus crispus* and its varieties may be said to grow in positions on the shore where they are usually submerged or kept constantly moist by running water, and they have a tidal range from the upper part of the mid-littoral belt to the sub-littoral zone.

In the Gower Peninsula the type species of *Chondrus* has been observed to occur in the littoral region immediately above the *Fucus serratus* zone, in shallow 'coralline' rock pools, and in sub-littoral sandy pools. In July and August the *Chondrus* often predominates in parts of the *F. serratus* zone, but in December the plants are much reduced in number, thus affording further evidence that *Chondrus* can behave as an annual. The plants have also been observed to extend into the *Ascophyllum* zone in an area where a geological fault forms a path for running water.

In order to determine the toleration of *Chondrus* for lowered salinity, water samples were taken at low tide from areas where *Chondrus* grew, at Port Eynon, Overton and Rhossili (Gower), and tested for salinity. The results for Port Eynon, tested on January 9th 1943, were as follows:

	S‰
Near a spring in the bay	15.4
In the main <i>Chondrus</i> area	27.2
Sea water in the bay	34.7

KEY TO THE CHART QUADRATS: TEXT-FIGS. 27 AND 28



Exposed rock surface or a stone



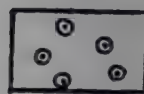
Sand



Shingle



Rock surface covered with *Lithothamnion Lenormandi* Foslie



Balanus balanoides



Patella vulgata

An *Ascophyllum nodosum* Le Jol.

AnePf *Ascophyllum nodosum* with epiphytic *Polysiphonia fastigiata* Grev.

AnePl *Ascophyllum nodosum* with epiphytic *Pylaiella littoralis* Kjellm.

Ap *Ahnfeltia plicata* Fries.

C *Chondrus crispus* (L.) Stackh.

Co *Corallina officinalis* L.

Dd *Dictyota dichotoma* Lamour.

Ec *Enteromorpha compressa* Grev.

Fs *Fucus serratus* L.

Fv *Fucus vesiculosus* L.

G *Gigartina stellata* Batt.

Lp *Laurencia pinnatifida* Lamour.

U *Ulva Lactuca* var. *latissima* D.C.

F† small plant of *Fucus* sp.

† small plant of either *Gigartina* or *Chondrus* (too small to be identified).

Here, as in the other localities tested, the water in which the *Chondrus* grew was of much lower salinity than normal sea water.

During July, August and September, *Chondrus* was observed to occur higher up the shore than during December and January. At Worms Head the plants were observed as high as the *Fucus vesiculosus* zone.

The occurrence of the plant in the littoral zone in pools, on rocky ledges, or in places where fresh water trickles across the shore, was observed also in parts of the Western Isles of Scotland, where *Chondrus* grew, though there it never attained the frequency of *Gigartina*. No investigations were attempted on the possible occurrence of sub-littoral forms but on Tiree there was an appreciable amount of *Chondrus* in the littoral zone, usually just above the *Fucus serratus* community. It was harvested by the crofters a few weeks earlier than *Gigartina* on tides that were not low enough to expose the latter plant.

The occurrence of fresh water trickling over the stones with or without pollution by farm sewage was observed on many occasions in the Western Isles to favour the growth of *Chondrus*, a condition that recalled strongly observations made in Wales, particularly in Anglesey. A gently shelving shore is also very favourable for the development of good harvesting beds, which latter usually occur at a higher level on the shore than those of *Gigartina*.

E. A. Lewis has frequently observed a pyrenomycete on *Chondrus*, towards the end of summer. It occurred on all forms of the plant, but was far more frequent on the sub-littoral var. *filiformis* Turn. and was well developed on plants which had lain for some time in piles of driftweed. The fungus frequently attacked the decaying tetrasporic or cystocarpic pustules, when it appeared

as conspicuous black spots. It has been assumed from its general characteristics that this is the *Didymosphaeria marina* (Rostr.) Lind. described by Rosenvinge (1931). The fungus was identified by I. M. Wilson (Aberystwyth) as *Leptosphaeria Chondri* (Rostr.) Rosenvinge: (*Didymosphaeria marina* (Rostr.) Lind.). It was first reported by Rostrup (1889) on the North Danish coast. The first British record was by Cotton (1908), who found it on plants washed up at Swanage, Dorset, in February 1908. It occurs also on attached plants at extreme low water of spring tides in July and August at Aberystwyth, and on driftweed at Aberystwyth and between Aberayron and Aberarth from September to December. This suggests that it starts life as a parasite and continues its development as a saprophyte. When occurring on plants washed up on the 'College rocks', Aberystwyth, in July, Wilson found that it formed conspicuous black patches in which were embedded minute flask-shaped pycnidia as well as perithecia containing asci. Each ascus contained eight bi-celled ascospores. The mycelium appeared to be confined largely to the fruiting portions of the thallus and has been found on both tetrasporic and carposporic pustules. This would account for the records of the fungus in February (Cotton, *loc. cit.*) and in July and the following months (Lewis, Wilson) corresponding to the two fruiting periods of the host.

Relatively little work has been done on marine fungi, though examination of drift weed in autumn confirms the opinion that there is considerable fungal attack on decaying thalli, or that the fungi cause some of the decay by attacking plants at the end of the fruiting season, so weakening them and making them the more susceptible to the action of winter storms. *Leptosphaeria Chondri* is being investigated further by Wilson.

EXPERIMENTAL WORK

Preliminary experiments on harvesting and weeding were carried out on the Gower coast and, as has already been described for *Gigartina* (p. 42 *et seq.*), preliminary results on methods of harvesting when *Gigartina* and *Chondrus* occurred together were obtained at Aberayron. All these results indicated that careless picking was a much more serious matter in harvesting *Chondrus* than *Gigartina*. The holdfast of *Chondrus* is less firmly attached and more easily torn away, partially, if not completely. Damage to the holdfasts is a serious matter because it prevents the regeneration of new shoots from them in the following spring. In addition, where the plants are growing on shingle, the disturbance of the substratum is very harmful, since it makes the pebbles more mobile and in subsequent rough seas almost all the algal vegetation on that particular part of the shore may be destroyed by friction. This was very apparent in areas such as that at Aberarth where algae other than *Chondrus* and/or *Gigartina* were weeded out. In contrast to the harmful

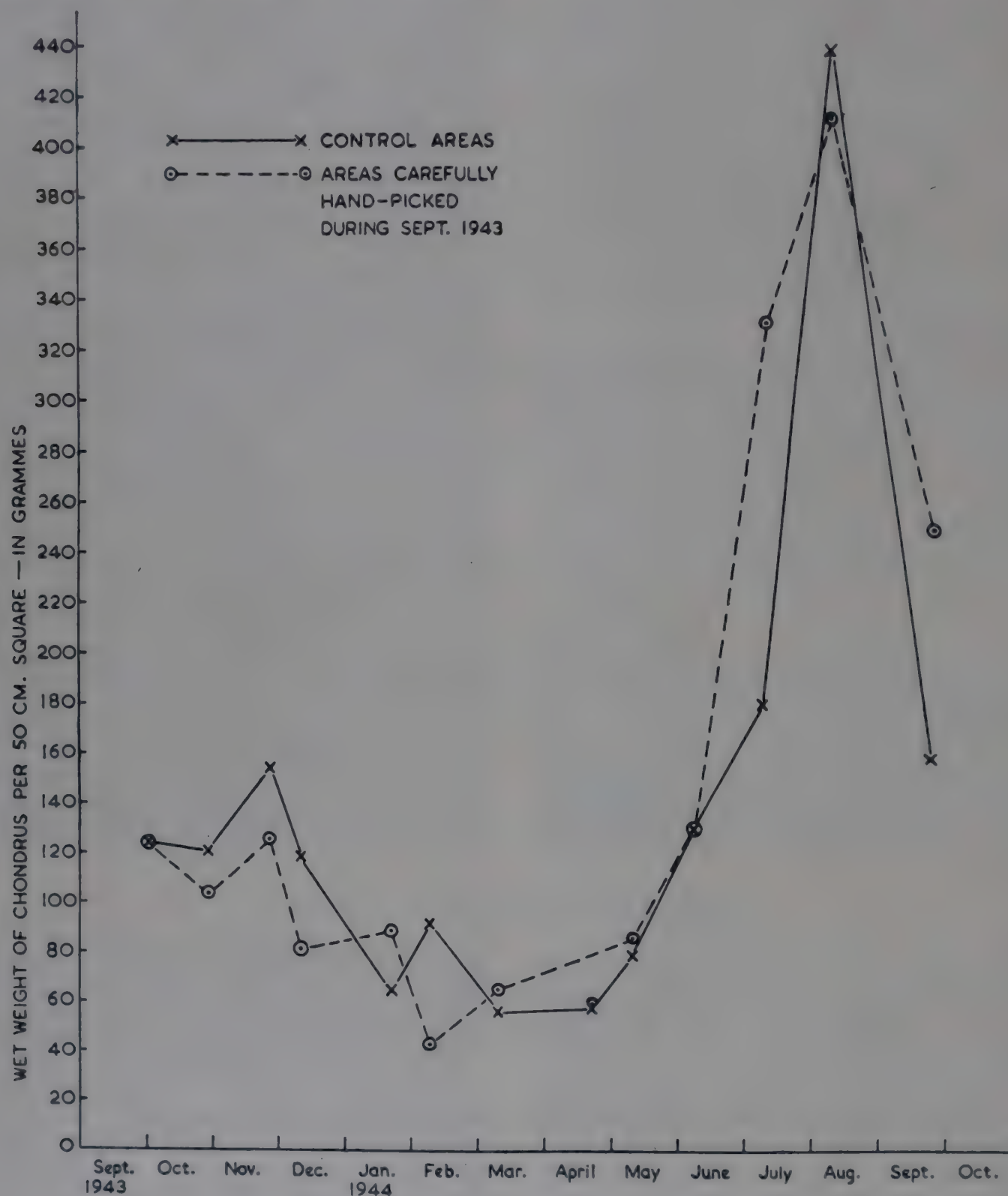
effect of bad picking, it was found that an area which had been 'well picked' (only half of the material gathered and the holdfasts left *in situ*) in one season, yielded a crop equal to that from a control plot in the ensuing year.

The results of bad picking were so conclusive that the work was not repeated (see p. 42, 1942-3 experiment), but it was thought advisable to verify that good picking was in no way detrimental to subsequent harvesting prospects. It was also desirable to find the monthly yield of *Chondrus* so that harvesting times could be fixed when the weight of seaweed was at its maximum, provided other factors were also favourable. An experiment with these aims was therefore undertaken in 1943. The area chosen was nearer to low water mark than the 1942 experiment. In such a position *Chondrus* was plentiful in the shingle pools, but there was no *Gigartina*. The experiment was however similar in method to that carried out earlier (see p. 42). A large area 10 × 6 m. was outlined with white paint on the shore at Aberayron and the *Chondrus*

present was 'well picked' from it in September 1943 (i.e. the holdfasts were not damaged). An area adjacent to the plot and at a similar tidal level was used as a control. The wet weight of *Chondrus* obtained from a 50 cm. square of the well picked plot and of the control were recorded each month. Each point on the graph (Text-fig. 29) is an average of two readings.

November, followed in the winter months by a marked decrease. The amount of material from the well picked plot showed a similar monthly curve and at the peak period was approximately equal to that from the control area.

It has already been stated that tetrasporic plants of *Chondrus* are most plentiful in winter and cystocarpic



TEXT-FIG. 29

The effect of careful picking during the previous season on the yield of Chondrus at Aberayron

It was necessary to pick the weed from a larger area than the 10 cm. square used for *Gigartina* in order to allow for error, since *Chondrus* is found in open communities (see Text-fig. 28).

The results showed that in the control plot *Chondrus* was most plentiful in the summer months, reaching a peak in August. There was a smaller peak in

plants in summer. The spores shed from these produce new plants, respectively, so that in one year there should be two periods during which sporelings of one type or the other are prevalent. The graph (Text-fig. 29) shows that there is a peak in August, due to the maturing of large numbers of cystocarpic plants, and a lesser peak in November due to the

tetrasporic plants. The latter peak, however, is much smaller, as it coincides with periods of rough seas when so much of the algal vegetation on the shingle beaches of Cardigan Bay is destroyed by the friction of the pebbles. Some of the plants probably live for two seasons or more, regenerating from the holdfast each spring, but frequently in Wales they are annuals (see anatomy of the holdfast, p. 53, and p. 54). Good picking, as already defined, was not at all harmful to the next season's crop. It is also apparent that *Chondrus* should be harvested between June and September to obtain the maximum amount of material. It is interesting to note that early August is considered the harvesting time for *Chondrus* in the Hebrides, though *Gigartina* is usually gathered for domestic use during the September tides.

Two experiments were commenced in September 1942 to show the effect of weeding out competitors on the growth of *Chondrus* in the littoral zone. It was obvious that if weeding increased the crop in any locality, a large scale experiment might have considerable commercial value.

In the first experiment, three one-metre quadrats were carefully selected and marked out on the shore at Aberarth, Cardigan Bay. All algae other than *Chondrus* were removed from them and the sides of the plot were cleared to prevent lateral overlap. The *Chondrus* present on the shore occurred under the thalli of *Fucus* plants, or as a dominant, or mixed with smaller algae in the shingle pools. It was not necessary to weed in positions where *Chondrus* was dominant and so two of the quadrats were marked out in areas where *Fucus* thalli overlapped the *Chondrus* in one case, and where numerous small algae were competing with it for dominance in the pools in the other. The third weeded quadrat comprised an area of sand-covered shingle and an adjacent rock on which *Fucus* plants were growing. *Chondrus* was already established on the shingle, but it was hoped to determine whether the plant would colonise the adjacent cleared rock surface. All the quadrats were kept weeded throughout the experiment.

Weight results after nine months showed that weeding had not increased the amount of *Chondrus* present, either when the overlapping *Fucus* plants had been removed, or when the smaller algae had been weeded out. One or two plants of *Chondrus*, however, were found recolonising the rock surface that had been cleared as a part of the third quadrat.

The second experiment was similar, but a larger area of shore was weeded. A belt transect 40×1 m. was marked out, and half of it was weeded of all algae other than *Chondrus*, while the remaining part acted as a control. This experiment was also commenced in September 1942 and the area was kept weeded throughout the experiment.

Weight results after nine months showed that in the weeded half there was approximately only one

third of the amount of *Chondrus* that was present in the control. During the winter months the smaller shingle had been piled up by the tide into the spaces cleared by weeding and most of the algal vegetation had been destroyed by friction. In the ensuing season therefore there was less *Chondrus* present than on that part of the shore acting as a control.

It was evident from the results that the limiting factor to the increase in the amount of *Chondrus* on a shingle beach such as at Aberarth was not competition from other algae. When any considerable area of shore was weeded the existing crop of the plant was actually lessened, as the shingle became more mobile and the algae were more easily destroyed by friction. A large scale experiment of this kind on shingle where *Chondrus* frequently grows would therefore have only a deleterious effect.

Weeding experiments were also carried out on three 1 sq. m. plots on the Gower coast. One plot had a thick covering of *Chondrus* and little weeding was necessary; in the second *Corallina* was dominant; the third was in the *Fucus* zone, where an undergrowth of dwarfed moss-like *Chondrus* plants was present. Control areas were kept under observation in all cases. The areas were mapped on September 9th 1942, and the number of *Chondrus* thalli over 2.5 cm. in length were counted in the following December and March, so that three-monthly periods intervened.

The numerical results obtained for the first area were as follows:

		December	March	<i>Gigartina</i> %
Weeded	....	2908	1185	5.0
Control	....	1437	860	1.6

The results showed a proportional decrease in the amount of ground covered by *Chondrus* plants in the two areas, as well as a reduction due to the wearing away of the fronds, leaving a denuded basal portion often less than 2.5 cm. in length. In both cases there were numerous thalli less than 2.5 cm. either because the distal parts of the plants had been broken off or because young thalli were developing.

In the area weeded of *Corallina*, the number of thalli over 2.5 cm. in length in December amounted to 1,700. A control area gave a similar result. The experimental quadrat was weeded again in December. Later, heavy seas were experienced and the loose stones to which the *Chondrus* plants were attached were nearly all removed. In March only 10 plants were present.

The area cleared of *Fucus* was mapped in August, September and again in December, by which time a change in the growth rate of the *Chondrus* plants was very evident. The thalli in August were about 6 to 12 mm. long and by December they were 5 to 7.5 cm. long, while those in the adjoining areas still covered by *Fucus* had not increased in size. No further marked differences were noticeable on the weeded quadrat in the following March.

The results show that *Chondrus* plants increased in size when weeding experiments were carried out in the *Fucus* zone, but it is doubtful whether such a venture would have any commercial value in Britain, where *Chondrus* forms so small a percentage of the total weed used for agar production. Where *Chondrus* is a more important crop, weeding experiments may be of value and it is reported that encouraging results have been obtained in Eire (Anon., 1939-40).

Preliminary results on areas scraped clear of algae in the zone where *optimum* conditions for *Chondrus* prevailed, showed that plots scraped in August had

begun to be recolonised by January, when in a one-metre square over 460 plants exceeding 2.5 cm. in length were counted. By March, the area was completely recolonised. It will be noted that this is much more rapid than *Gigartina* recolonisation, and also that *Chondrus* appeared to be the first macroscopic coloniser of the denuded area.

In view of the fact that so small a percentage of the total harvest in Britain proved to be *Chondrus*, no further experimental work was carried out on the shore, though an investigation of seasonal fluctuation in gel strength continues.

III. HARVESTING OF *GIGARTINA STELLATA* AND *CHONDRUS CRISPUS*

DECISIONS regarding large-scale harvesting were made periodically from 1942 onwards. In view of the national emergency, it was necessary to begin to harvest before the autecology of the plants had been studied and before the surveys were complete. In addition, information on the chemical side of the work influenced certain aspects of the harvesting problem as new facts became known. Fortunately it was not necessary for the harvesters to separate *Chondrus* and *Gigartina*; in practice, only 5% of the total harvest was *Chondrus*.

In 1942 harvesters were instructed not to take more than half of the available material and to gather from May to September at the periods of spring tides. Later, as more information became available about the growth of the plants and the time when the gel strength increased, the starting dates were modified, first to the month of June and then later to July. When it had been ascertained that even in the best areas the harvesting of two crops a year was not desirable (see p. 49), there was obviously nothing to be gained by taking an early harvest; it was far better to wait and harvest at a time when the crop was at its maximum both in weight and gel strength. As facts became established concerning the re-growth of the plants, from the holdfast and by regeneration from old thalli, in the case of both *Gigartina* and *Chondrus*, harvesters were instructed to pick all available material. Particular instruction was given that hand picking and not shearing was to be employed, as this latter would have impaired future crops.

Harvesting was not desirable after September, partly because of the physical difficulties of getting access to the weed during the autumn gales and also because at that time the *Gigartina* plants shed their spores. In the rich Scottish areas much of the ungathered *Gigartina* is washed away in the autumn when the plants are large and heavy. As has already been stated this drift material is not suitable for harvest, but it is believed to be valuable for dispersal of the spores. Further

observations on the exact time of spore-shedding are in progress.

Some experimental work has been carried out by E. H. Chater on various aspects of the drying of *Chondrus* and *Gigartina* using plants gathered on Anglesey or on the Gower Peninsula (Wales).

When gathered fresh, and air-dried, the loss in weight with *Gigartina* is about 60% and with *Chondrus* 70% of the original weight. These air-dried seaweeds still contain about 20% moisture depending on the humidity of the air; if dried by heat to a lower moisture content they will gradually regain moisture up to this amount from the air (see Table 6).

TABLE 6
CHANGES IN WEIGHT OF DRIED MATERIAL DURING STORAGE

DAYS STORED	WEIGHT OF WEED	% INCREASE IN WT.
	gm.	
0	4,208	
5	4,315	2.5
12	4,380	4.1
19	4,400	4.6
67	4,535	7.8

Experiments were also carried out both with *Chondrus* and *Gigartina* to find the effect of washing the weed with salt and with fresh water. The results are shown in Table 7. The plants were immersed either in sea water or in fresh water and air-dried. Those dried from fresh water had a higher percentage loss than those dried from sea water, presumably owing to the loss of adherent salts.

Those dried from sea water, when re-soaked in sea water, did not regain all their initial water, but if re-soaked in fresh water increased considerably above their original weight. With those dried from fresh water and

TABLE 7

EFFECT OF RE-SOAKING GIGARTINA AND CHONDRUS IN FRESH OR SEA WATER

The figures indicate percentage of original fresh weight, when equilibrium with air or water had been reached

<i>Gigartina</i>						
Dried from sea water	37.1*	{	Re-soaked in sea water†	86.8	Dried	32.6
			Re-soaked in fresh water†	108.9	Dried	29.5
Dried from fresh water	29.3*	{	Re-soaked in sea water†	76.6	Dried	28.3
			Re-soaked in fresh water†	100.2	Dried	25.5
<i>Chondrus</i>						
Dried from sea water	26.1†	{	Re-soaked in sea water‡	77.6	Dried	23.4
			Re-soaked in fresh water‡	119.4	Dried	18.6
Dried from fresh water	21.9†	{	Re-soaked in sea water‡	74.3	Dried	23.0
			Re-soaked in fresh water‡	94.4	Dried	16.8

*Average of 12 plants.	†Average of 6 plants.	‡Average of 3 plants.
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*Average of 12 plants.

†Average of 6 plants.

‡Average of 3 plants.

re-soaked in sea water, the uptake of water was low, but when re-soaked in fresh water was the same as the original. While similar effects were indicated by the figures for a second re-soaking of *Gigartina* in fresh or sea water, the weed was beginning to decay and the results are not reliable.

The experiments indicate that *Gigartina* or *Chondrus* exposed to fresh water or rain after harvesting will show a very considerable increase in fresh weight. It is desirable therefore to protect the weed from rain after picking since subsequent drying will take longer.

It was also necessary to ascertain the length of time during which it might safely be assumed that wet *Chondrus* and *Gigartina* could be transported in bulk. The two algae were dealt with separately.

Material was gathered from Trearddur Bay, Anglesey, and kept in sacks. It was examined daily after the third day from gathering. A sample handful was taken from the centre of a sack, each day from further down, so that each sample was of undisturbed and tightly packed material. The results are summarised in Table 8.

TABLE 8

EFFECT OF STORING WET GIGARTINA AND CHONDRUS

DAY	GIGARTINA		CHONDRUS	
	ODOUR	APPEARANCE	ODOUR	APPEARANCE
3rd	Fresh	Normal	Fresh	Normal
4th	"	"	"	"
5th	"	"	"	"
6th	"	Slight loss of colour at tips	Less fresh	"
7th	"	" " "	" "	"
8th	"	" " "	" "	"
9th	"	Tips markedly lighter	" H ₂ S	"
10th	Slightly altered	" "	" "	"
11th	"	" "	" "	"

These results indicate that *Gigartina* and *Chondrus* are not likely to undergo any appreciable deterioration for several days after gathering. It would appear that both keep fresh for at least five days and that *Gigartina* continues to smell fresh for a further three or four days. Some heating may occur in stored weed.

It is suggested that the poorer keeping quality of *Chondrus* may be due to its softer texture, its frequent rock pool habitat, and the consequent greater probability of contamination by micro-organisms.

Though these experiments were only of a preliminary character the results enabled instructions to be issued to harvesters. It was possible to decide whether harvesting was practicable in any given area, having regard to the problem of transporting the wet weed to some place where drying could be accomplished. Local trade-vans were often used, voluntarily, to transport wet weed and private cars were the means of much transport when lorries were not available. The experiments also indicated that the weed could be stored for a day or so if necessary before drying and some information could also be deduced concerning the effects of sudden showers on gathered weed awaiting transport, or on spread weed which was partly dry.

It was also decided that after the weed had been gathered into bags it should either be despatched to a drying station or dried locally. In the latter case the weed was first washed for a few minutes in enough fresh water to cover it and then spread out to dry. This removes the adherent salts but does not obviate the necessity of washing before manufacture. Difficult though the harvesting was, the problem of washing and drying was of even greater magnitude. During washing, the weed had to be cleaned from sand, epiphytes, and other organisms where possible, before it was dried. Considerable ingenuity was exhibited in carrying out these processes; for example, a small stream was dammed to make a washing pool in one area and a large bath was used in another. The warm

air from a village bakery, a spare corner in a herb-drying shed, shelves of greenhouses and many other devices supplemented the very intermittent sunshine and enabled the drying to be accomplished.

On a larger scale, drying of *Gigartina* from some of the Western Isles of Scotland was carried out at a biscuit factory in Airdrie*, where the waste heat from the top of the building was conducted downwards by fans to the lower floors to dry the weed. In Cornwall an old kiln was used for drying and in London a drying station was set up at Messrs. Paines and Byrne's factory at Greenford. One practical difficulty proved to be the enormous bulk of the dried material. It became horny and stiff during drying and occupied much more space than it had done when wet.

Utilisation of *Chondrus* and *Gigartina* for anything other than agar production was prohibited by an Order in Council, controlling the harvest and the utilisation of available material.

Harvesting was carried out in England and Wales by volunteers from among the Scouts, Guides, Sea Scouts, Rangers, Junior Red Cross, W.V.S., W.R.I.'s, lighthouse keepers, R.A.F., schools and private individuals, as well as through the official organisation of County Herb Committees. The weed was despatched wet or dry, according to whatever arrangements had been possible, and the firm of Messrs. Paines and Byrne remitted a poundage to the local organisers. In many cases this money was subsequently donated to war charities. At first it was difficult to ensure that the correct weeds were gathered and an algologist was put in charge of every collecting area. A few visits were usually necessary to teach the local harvesters to identify the particular form or forms of the weeds in a particular locality and afterwards difficulties were dealt with by correspondence. In Scotland the position was different, because in the good harvesting areas the almost closed

consociations of pure *Gigartina* are a conspicuous feature of the shores and in some areas *Gigartina* is well known and is harvested as 'carrageen' quite regularly by the crofters for domestic use. Around the Scottish islands it was possible to obtain a very much greater weight of weed in a given time than was possible in the harvesting areas of the south. For this reason the poundage was sufficiently attractive to enable the work to be carried out on a commercial basis, especially in parts of the Clyde sea-area.

The total harvest figures for the various areas during the years 1943-45 are shown in Table 9.

Considering the great difficulty of clambering over slippery rocks and traversing them almost to low water mark, the weight of a bag of wet seaweed, the relative inaccessibility of many of the coasts and the lack of adequate roads to the shore, it is a very great tribute to all those who worked so indefatigably to gather this essential raw material, that no serious accident took place during harvesting.

It will be observed that there has been no falling off in the total harvest over the years though bad weather seriously hampered local drying in certain areas in 1945. In practice two relevant points have been noticed, firstly, that in a given area the maximum weight of the crop tends to be a little later if it has been closely harvested the previous year, and secondly, that close picking for two successive years in an area of *Chondrus* and *Gigartina* in the south of England appeared to result in a less good yield from that area in the third year. No such deductions have been made from the rich Scottish areas, but precise records are being kept of the effects of harvesting an area of *Gigartina* annually over a period of years.

Having regard to the labour involved in harvesting a given weight of *Chondrus* and *Gigartina* in localities in England and Wales, and in obtaining the same

TABLE 9

WEIGHT OF GIGARTINA AND CHONDRUS HARVESTED ANNUALLY IN BRITAIN, 1943-1945

	1943		1944		1945	
	WET lbs.	DRY lbs.	WET lbs.	DRY lbs.	WET lbs.	DRY lbs.
ANGLESEY	—	2,629	—	4,153	—	1,468
CORNWALL	14,296	125	—	14,064	—	14,594
DEVON	1,014	1,989	—	5,108	—	1,140
DORSET	—	38	—	109	—	51
GLAMORGAN	2,730	—	—	—	—	—
NORTHUMBERLAND	—	1,293	—	389	—	684
SCOTLAND	12,015	27,115	123,229	3,721	129,630	2,542

*Further notes on the commercial drying station at Airdrie are contained in the Ministry of Supply Permanent Record Monograph, No. 11,145. (Appendix C).

amount of *Gigartina* from prolific Scottish areas, it would appear that only from the latter could a profitable harvest be obtained in peace time. The labour involved in harvesting the weed in England and Wales in

war time was more than justified on account of the needs of essential health services, but the areas are scattered and the plants never form the close 'mat' that can be seen for example around the Cumbrae.

IV. CHEMICAL WORK

TESTS ON RED SEaweEDS

SINCE little was known of the gel-producing properties of extracts of British red seaweeds, the commoner among them were tested. For a preliminary examination the seaweed was rinsed in fresh water and dried at a temperature not exceeding 80° C. A weighed quantity of the dry weed was then boiled for several hours either in distilled water or in distilled water made slightly alkaline with lime. The residual weed was screened off through fine cloth and the filtrate allowed to stand. If a gel formed on cooling it was cut into strips, frozen, thawed and then air-dried. On freezing and thawing the thaw water carried away a considerable amount of the dissolved salts and other impurities. After drying, solutions of different strengths were made to test the gelling power.

An agar suitable for bacteriological work should be able to hold a slope at 37·5° C. (see p. 102) in a suitable concentration and, for economic reasons, the lower the concentration the better. It should support bacterial growth in the usual media but contain neither growth-promoting nor growth-inhibiting substances. The melting point is not very important but the setting point should be below 40° C. The surface of the gel when cold should be firm enough to be stroked with a metal loop without fracturing. A small amount of synaeresis is desirable but a large amount causes too moist a surface and a risk of confluent colonies of organisms growing on the agar. The gel strength should be as great as that of Japanese agar.

The following results were obtained: *Delesseria sanguinea*, *Ptilota plumosa*, *Ceramium rubrum*, *Dumontia incrassata*, *Dilsea (Iridaea) edulis*, *Gloiosiphonia capillaris*, and *Rhodymenia palmata* gave no gel.

Laurencia pinnatifida gave a weakly gelling extract of which a 3% solution did not hold a slope at room temperature; the gel was brittle. *L. caespitosa* gave no gel. *Polysiphonia fastigiata* gave a weak but syrupy gel which did not hold a slope in 3% solution. *Cystoclonium purpureum* gave a very weak gel in 1% solution. *Phyllophora membranifolia* gave a very weak gel in 3% solution. *P. epiphylla* also formed a very weak gel.

Gelidium corneum

This alga is scarce on the Cumbrae and a sample of about 15 gm. dry weight was obtained from Port St. Mary, Isle of Man. 5 gm. were boiled for about 7 hours with 250 ml. distilled water, filtered and treated

as described above. The yield was 1·15 gm. agar, i.e. 23% of the original seaweed. When tested bacteriologically it was found to be as good as imported agar. The results of tests on this and other laboratory-made agars will be found in Table 20, p. 90.

A sample was also collected at Dunure, Ayrshire, and treated in the same way. As collected the weed was mixed with *Corallina* and *Leathesia* and it was calculated that it would require an hour to collect and sort 250 gm. of air-dried *Gelidium*. This sample yielded only about 20% of its dry weight as agar.

Ahnfeltia plicata

Only small quantities of this seaweed were available on the Cumbrae and a sample of 33 gm. air-dried material was obtained from the east coast of Scotland. This was extracted with lime (5% of weight of seaweed) for an hour in an autoclave at 4 lb./sq. in. as recommended by Kizevetter (1937a). On treatment in the usual way it provided 1·8 gm. agar, a yield of 5·4%. The residue was extracted for a second, longer period, under pressure and the total yield raised to 10%. It was found to be as good for bacteriological work as Japanese agar.

A series of samples from Northumberland gave much the same results. A yield of about 5-15% agrees with that obtained in Russia (Kizevetter, 1937a).

Gracilaria confervoides

Samples of this and the following alga were obtained from Plymouth. A sample was boiled in distilled water for 4-5 hours and after treatment gave a yield of about 30% of the dry seaweed. Further extraction added little to the yield. Although inferior to *Gelidium* agar it is suitable for bacteriological work.

Gracilaria multipartita

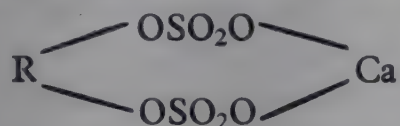
This alga is rarer than *G. confervoides*. Treated in the same way the yield was only 17% of the air-dried seaweed and the resulting product slightly inferior in quality.

It is apparent that the properties of the extracts from different seaweeds of the same genus are not necessarily similar and that gelling is not restricted to the extract of any particular Order or Class. The prominence of members of the Gigartinales in commercial agar manufacture is however noteworthy.

PRELIMINARY WORK ON GIGARTINA STELLATA

Since all the red weeds which yielded suitable gels on boiling with water were too scarce for commercial harvesting, attention was turned to *Gigartina stellata* Batt. which had not formerly been regarded as an agar-producing weed (Tseng, 1945b). This yields over 50% of its dry weight as an extract which forms a soft and viscous gel. This extract without further treatment is quite unsuitable for bacteriological work since it will not hold a slope at room temperature even in a strength of 6%. Owing to its viscosity it is very difficult to make a solution of this strength.

Haas and Hill (1921) suggest that the extract is an ethereal sulphate of calcium of the following type :



The results of Haas and Russell-Wells (1929) suggest that certain chemical treatment of the extract might lead to an improvement in the quality of the gel. They found that on hydrolysis of the "hot water extract" from carrageen* with alcoholic potassium hydroxide, three substances were produced one of which (hot water soluble) was found to have a gelling power five times as great as the original substance. This they thought to be the potassium salt of the original hot water extract. They also showed that the potassium salt prepared by double decomposition from the original extract (which is a calcium salt) had a greater gelling power. Haas and Hill (1921) also state that a small quantity of Rochelle salt effects a great increase in the gelling power of carrageen extract.†

Sauvageau (1921) has also shown that the extract from several seaweeds including *Chondrus* and *Gigartina* has an increased gelling power in the presence of certain salts, especially potassium chloride. More recently this information has been used in the preparation of *Chondrus* jellies for the food packing industry. A patent for the use of potassium chloride in *Chondrus* extract was taken out by Leon (1929); his results were confirmed by Reedman and Buckby (1943) and a manufacturing process was outlined by Fulton and Metcalfe (1945).

Gigartina was therefore extracted by boiling it with lime water (2-6% CaO on the weight of the weed) and screening the residue off through muslin. On cooling, the extract set to a weak gel which was cut into strips, dried by laying out on muslin in a warm room and ground to a flaky powder. This dried extract was used in a series of experiments to find out how the gelling power might be increased.

Haas and Russell-Wells' treatment of the extract with alcoholic potassium hydroxide was repeated but the substance obtained, although differing from the original,

did not show a markedly greater gelling power. The presence of alcohol (methyl, ethyl, propyl, n-butyl, and amyl) in a solution of the lime extract does, however, increase the gelling power.

Solutions of the extract were then treated with a number of calcium precipitating salts to form the potassium, ammonium, and sodium, ethereal sulphates. It was noticed that on boiling with a number of these substances, e.g. potassium oxalate and potassium dihydrogen phosphate, the solution suddenly became much thinner. The same happened with potassium hydroxide and potassium carbonate if, after boiling, the solution was neutralized with hydrochloric acid. The gels formed from these thin solutions were firmer and showed a greater slope-holding capacity. Of these solutions, that produced by boiling with potassium hydroxide and neutralizing with hydrochloric acid formed a fairly satisfactory gel as judged from its slope-holding capacity. On analysis after dialysis however it was found not to be a pure salt but to contain both potassium and calcium (about 3% CaO). For production of the pure compounds the most convenient precipitants were found to be the oxalates and by boiling the extract with these, dialysing, filtering, and drying, substances were obtained which contained no calcium and gave gels in high concentrations. The calcium salt was prepared by purification of the lime extract with alcohol (Butler, 1934) and contained 4-5% CaO. The potassium, sodium and ammonium compounds gave non-viscous solutions, whereas those of the calcium compound were always very viscous. These substances were used for testing the effects of various electrolytes on gelling.

CALCIUM COMPOUND

The gels formed by the calcium compound were weak and soft; a 1% solution scarcely gelled, a 2% solution would not hold a slope at room temperature, a 3% solution held a slope at room temperature but not at 40° C., a 5% solution held a slope for 24 hours but not for 48 hours at 40° C., 7% and 9% solutions held a slope at 40° C. indefinitely. The higher concentrations were very difficult to dissolve and gave very viscous solutions. The dry extract imbibed water freely.

The gelling power and melting and setting points were however much altered by treatment with certain salts. Preliminary tests in which comparatively large quantities of salts were added to a 3% solution of the agar showed that some of them had a distinct effect on the gelling power in that a 3% solution then held a slope at 40° C.

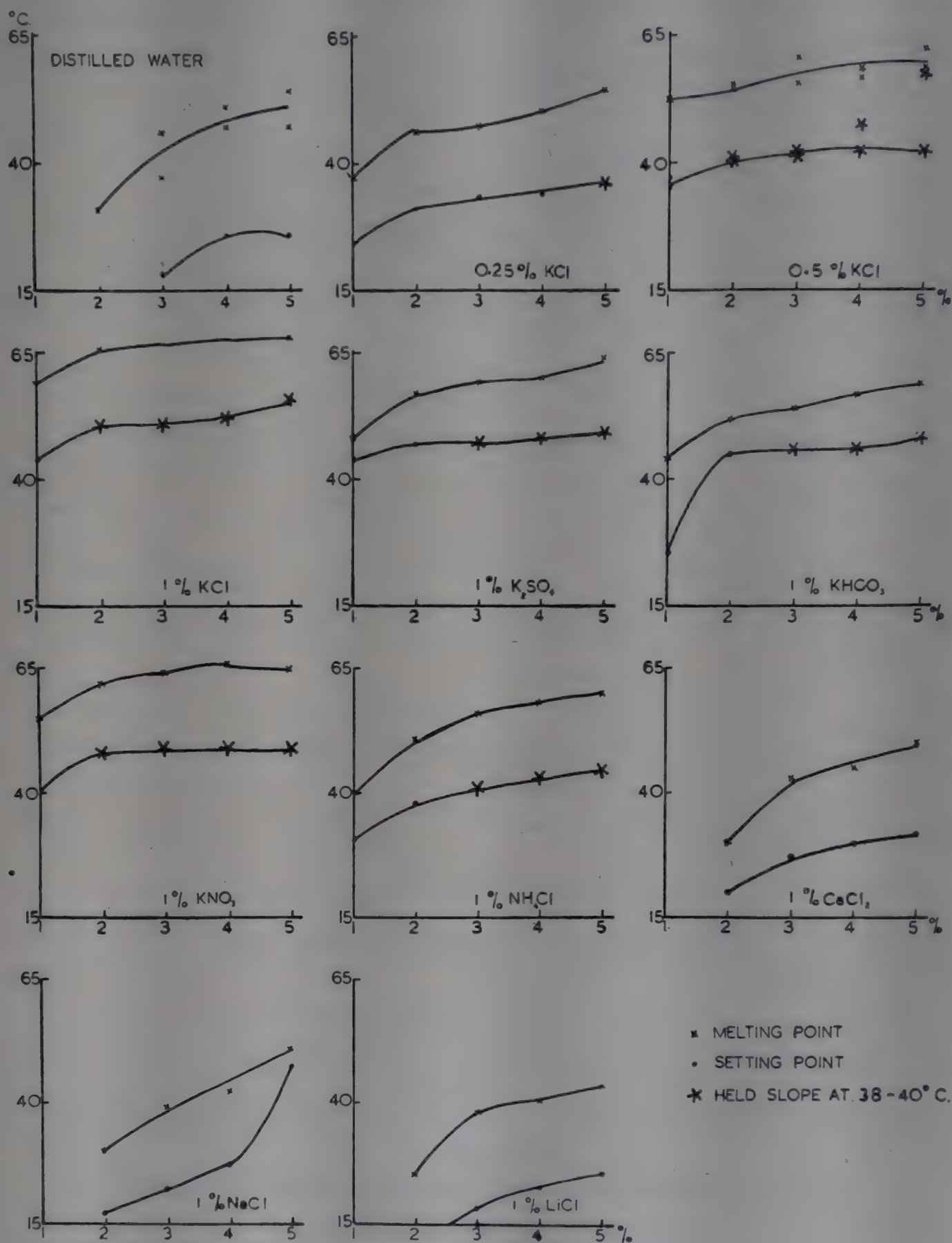
In order to find out the effect of different anions and cations, a sample of the lime extracted substance was

*The weed used by these authors was commercial carrageen which is usually bleached and is a mixture of *Chondrus crispus* (L.) Stackh. with a small quantity of *Gigartina stellata* Batt.

†To test this a *Chondrus* hot water extract was dialysed, made up in 1% potassium chloride and 1% Rochelle salt and the gel strength measured; although both salts increased the gel strength the effect of the former was much greater.

purified by alcohol, dialysed to free it from electrolytes, and, after drying, made up in strengths from 1-5% in 1% solutions of various salts (see Text-fig. 30). These

solution held a slope in lower concentrations than before. The effect of KCl is marked even in 0.25% solution. Although the melting and setting points were raised,



TEXT-FIG. 30

The effect of electrolytes on the dialysed calcium compound from Gigartina

Ordinates = temperature in °C.
Abscissae = % strength of agar solution.

The * indicates the setting point and that the gel when set held a slope at 38-40° C.

(Based on data contained in Table A in the Ministry of Supply Permanent Record Monograph No. 11,145)

show that the effect of $K^+ > NH_4^+ > Ca^{++}$, Na^+ or Li^+ , and that of $Cl^- > NO_3^- > HCO_3^-$ and SO_4^{--} . In all cases the melting and setting points were raised and the

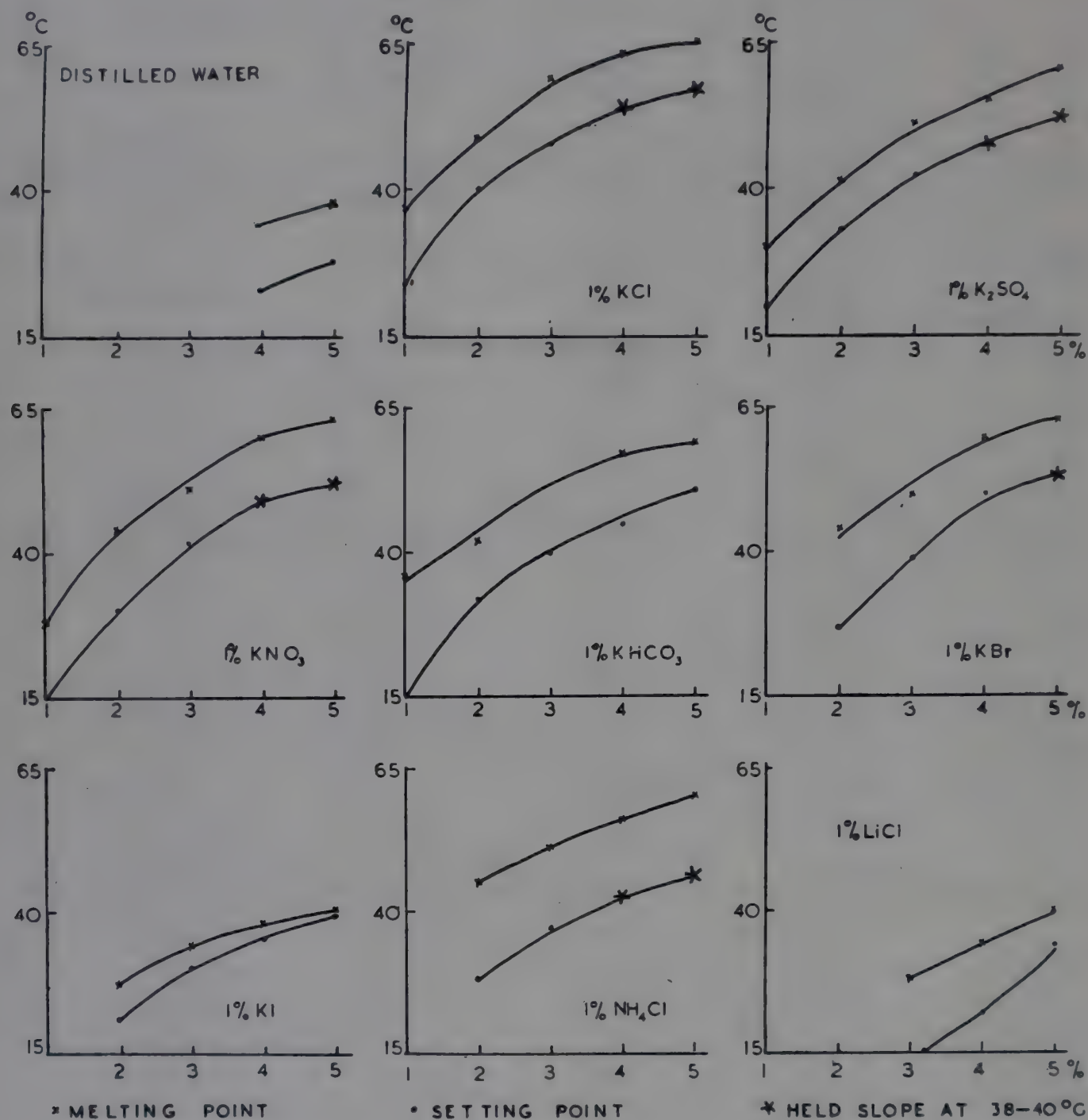
the range between them (less than 20° C.) was not altered nor was it found possible by any subsequent treatment to make any great change in this.

POTASSIUM COMPOUND

500 gm. *Gigartina* were extracted with lime as before and screened. 60 gm. potassium oxalate were added to the filtrate when hot, the whole boiled for about 2 hours and then made slightly acid with hydrochloric acid. It was filtered through No. 1 Whatman paper and dialysed against distilled water till free from chloride. When

Contrary to the finding of Haas and Russell-Wells (1929) with *Chondrus*, therefore, the purified potassium compound from *Gigartina* does not have a greater gelling power than the calcium compound.

In 1% solution of different electrolytes the effect of K^+ was $> NH_4^+$; the effect of $Cl^- > NO_3^- > HCO_3^-$, SO_4^{2-} or Br^- , $> I^-$.



TEXT-FIG. 31

The effect of electrolytes on the dialysed potassium compound from Gigartina

Ordinates = temperature in °C.

Abscissae = % strength of agar solution.

The * indicates the setting point and that the gel when set held a slope at 38°-40° C.

(Based on data contained in Table A in the Ministry of Supply Permanent Record Monograph No. 11,145)

dried the ash content was 22.31% and there was only a trace of calcium present. This calcium-free agar was used to test the effect of different electrolytes and the results are shown in Text-fig. 31.

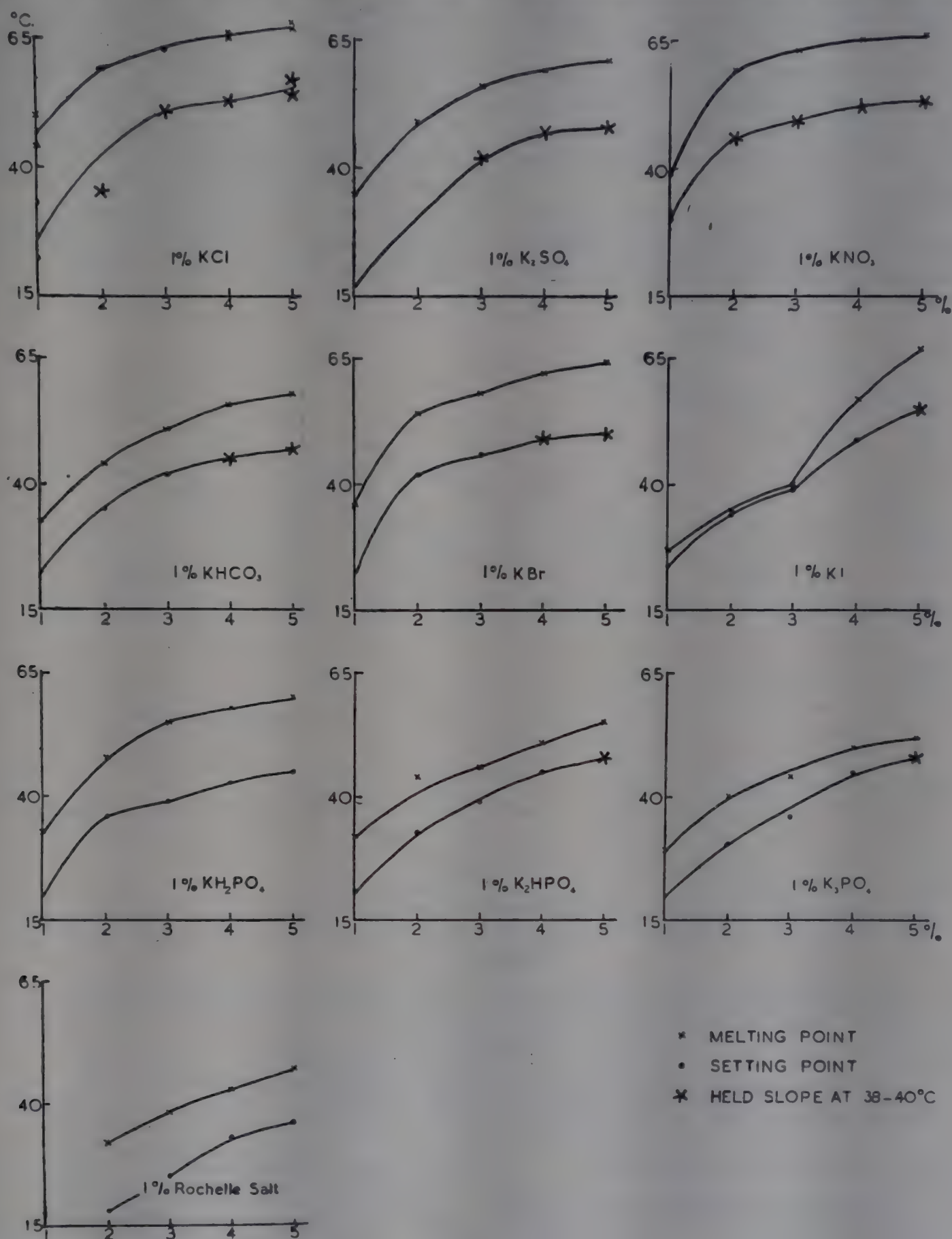
When made up in distilled water the potassium compound did not hold a slope at 40° C. even in 8% solution.

From the point of view of the tests chosen (melting point, setting point and ability to hold a slope at 38-40° C.) the potassium compound in the presence of KCl is not so good as the calcium compound, but on the other hand it is readily soluble and the hot solutions have a low viscosity. The gel is also more brittle than that of the calcium compound. The potassium agar does

not imbibe water at room temperature to anything like the same extent as the calcium agar.

An attempt was also made to obtain the potassium

brittle, dark-green gel which, when dried and made up in 5% solution, held a slope at 38-40° C. On ashing it was found to contain 0.24% CaO. From its colour and



TEXT-FIG. 32

The effect of electrolytes on the dialysed Ca : K compound from Gigartina ; anions

Ordinates = temperature in °C.

Abscissae = % strength of agar solution.

The * indicates the setting point and that the gel when set held a slope at 38°-40° C.

(Based on data contained in Table B in the Ministry of Supply Permanent Record Monograph No. 11,145)

compound directly by extracting the weed with potassium oxalate. 500 gm. Gigartina were extracted with an excess of potassium oxalate (120 gm.). The extract, which was very thin when hot, set to a hard,

appearance it was obvious that the extract obtained by oxalate was not the same as that obtained by lime and was not so suitable.

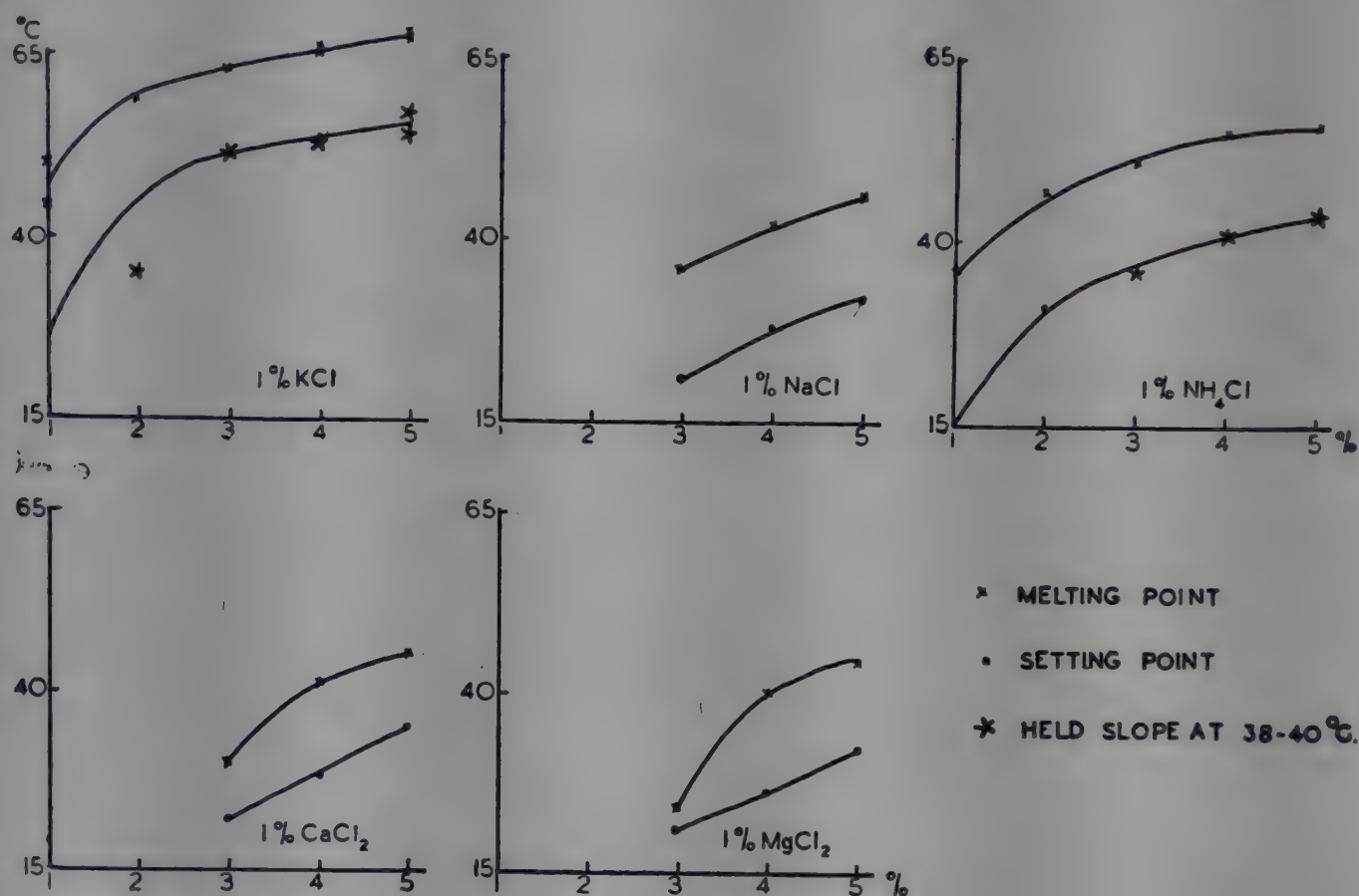
Much the same results can be obtained by using

phosphates or carbonates of potassium instead of oxalate. Should the solution be alkaline or acid, it is necessary to neutralize with hydrochloric acid or potassium hydroxide before filtration, and with carbonates neutralization is troublesome because of frothing. *Gigartina* was extracted using potassium carbonate instead of lime in a quantity sufficient to replace all the calcium present. After making slightly acid it was filtered and dried. The gel obtained was similar to that obtained by oxalate extraction.

Extraction with potassium hydroxide gave a hard, tough dark-green gel. It held a slope in 4% solution but was difficult to dissolve and left an insoluble residue.

bacteriological work. A sample of this material was tested bacteriologically and favourable reports were received.

As already mentioned, analyses of dialysed samples showed that only part of the calcium had been replaced by the potassium. Solutions of the dialysed material however would not hold a slope even in 7% solution. It seems therefore that the gelling properties of the undialysed material are dependent on the salts present, i.e. on the potassium chloride formed on neutralization. A series of tests was therefore made by dissolving the dialysed material in 1% solutions of various electrolytes. The results are shown in Text-figs. 32 and 33. Of



TEXT-FIG. 33

The effect of electrolytes on the dialysed Ca : K compound from Gigartina ; cations

Ordinates = temperature in °C.

Abcissae = % strength of agar solution.

The * indicates the setting point and that the gel when set held a slope at 38°-40° C.

(Based on data contained in the Ministry of Supply Permanent Record Monograph No. 11,145)

MIXED POTASSIUM-CALCIUM COMPOUND

On heating the lime extract of *Gigartina* with enough potassium hydroxide to replace all the calcium, a part only of the calcium in the gel is replaced by potassium and the solution becomes less viscous. On neutralizing with hydrochloric acid it becomes still thinner and changes in colour from green to yellowish-brown. If kept hot it can be filtered through ordinary filter paper and sets to a clear brittle gel. When dry it is easy to dissolve and gives a clear, non-viscous solution which holds a slope in 3-5% on setting.

This was the most promising method of improving the calcium extract so far found and in addition the substances added seemed to be unobjectionable for

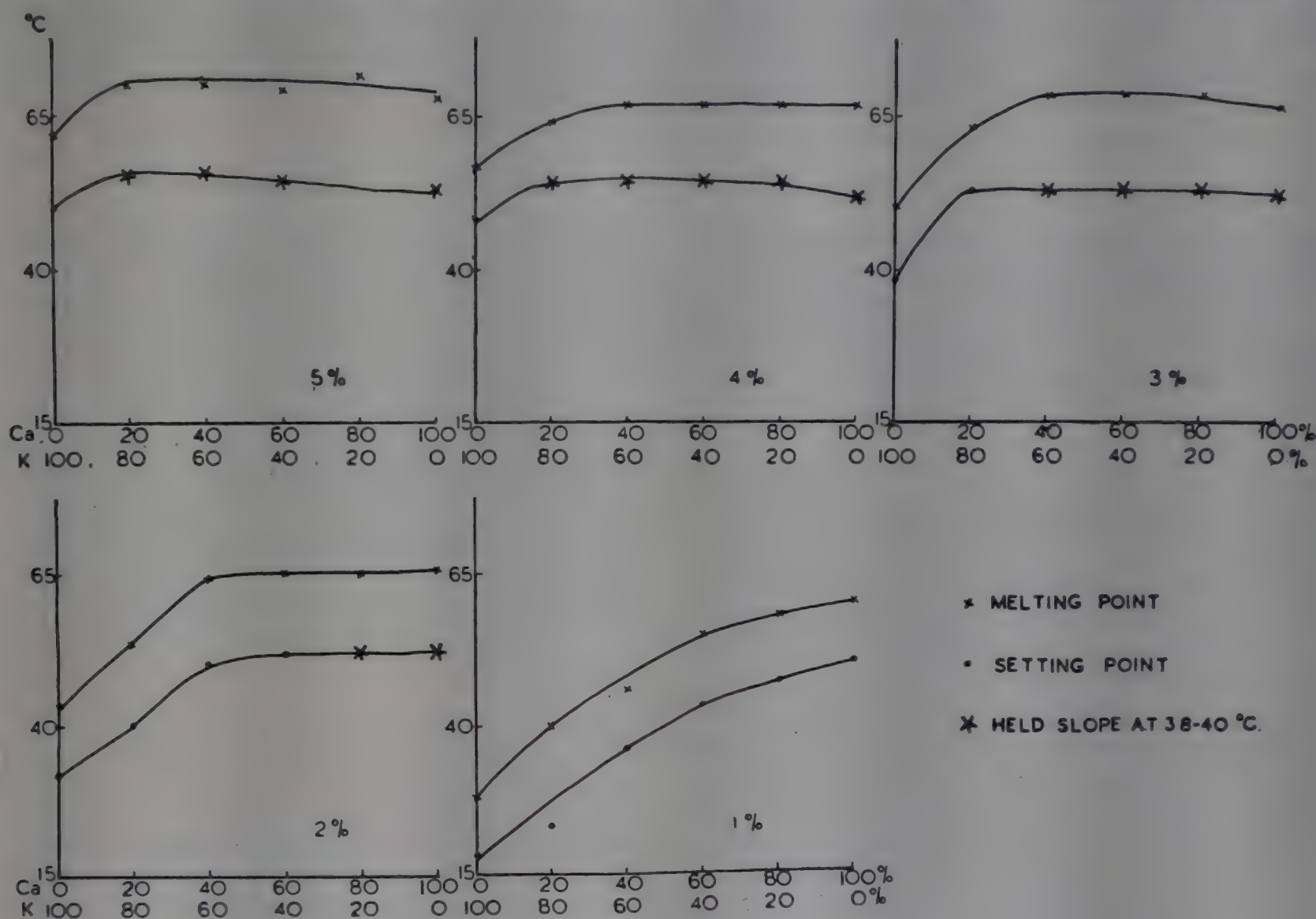
the anions the effect of $\text{Cl}^- > \text{NO}_3^- > \text{Br}^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{H}_2\text{PO}_4^-$, HPO_4^{2-} , and PO_4^{3-} . The effect of potassium iodide was to make the gel very elastic and the melting points and setting points did not lie on a smooth curve as with the other salts. Of the cations the effect of $\text{K}^+ > \text{NH}_4^+ > \text{Na}^+$, Mg^{2+} , or Ca^{2+} . Rochelle salt which was recommended by Haas and Hill (1921) was found to have an effect much less than most of the other salts tested (see also pp. 64 and 72).

In all cases the melting and setting points were raised and the setting point was often too high for bacteriological requirements. As is shown in Text-figs. 32 and 33, the solution in 1% potassium chloride was the only one which held a slope in 2% at 38-40° C. (although

it failed to do so in a second test); several others held a slope in 3% solution or higher. Rubidium chloride has an effect similar to that of potassium chloride.

The effect of varying concentrations of potassium chloride on melting and setting points was examined. There was a continuous rise of both with increasing potassium chloride, up to 2.5-3%, but the effect was much more marked when the agar solution was weak (1%) than when it was strong (5%). When the amount

both have some desirable properties, it was thought that a suitable bacteriological agar might be formed from a mixture of the two. Mixtures of varying proportions in varying strengths were made up in 1% potassium chloride. These were tested as before and the results are shown in Text-fig. 34. Except in 1% solution and to a lesser extent in 2% solution, even when only a fifth of the mixture was the calcium compound, this seemed to have a preponderating effect since the melting points



TEXT-FIG. 34

Melting and setting points of mixtures in different proportions of the dialysed Ca and K compounds from Gigartina, made up in 1.0% KCl

Ordinates = temperature in °C.

Abscissae = % strength of agar solution.

The * indicates the setting point and that the gel when set held a slope at 38°-40° C.

(Based on data contained in Table C in the Ministry of Supply Permanent Record Monograph No. 11,145)

of potassium chloride exceeded about 3% there was little further effect.

The amount of potassium hydroxide ordinarily used was 5% of the weight of dry seaweed. When this was reduced to 1.7%, the extract treated in the usual way, and potassium chloride added up to the amount normally present, it was not apparently different from the solutions made with the full amount of potassium hydroxide. When, however, this extra potassium chloride was not added, the solutions did not hold a slope in the usual concentrations.

Since the pure potassium and pure calcium compounds

and setting points were as high as with the pure calcium compound.

AMMONIUM COMPOUND

10 gm. of Gigartina lime extract was boiled with 4 gm. ammonium oxalate for 30 minutes and then filtered and dialysed against distilled water. It formed a very weak gel which just set in 5% solution at room temperature. The ash contained no calcium.

SODIUM COMPOUND

10 gm. of Gigartina lime extract was boiled with 4 gm. sodium oxalate for 30 minutes and then filtered

and dialysed against distilled water. It formed a very weak gel which just set in 5% solution at room temperature. The ash contained only a trace of calcium. In contrast to the potassium and ammonium compounds it formed very viscous solutions. Even when made up in 1% potassium chloride, a 5% solution did not hold a slope at 38-40° C.

This preliminary work showed that the compound containing both calcium and potassium was the most promising* for making bacteriological agar, and that potassium chloride was the most suitable electrolyte for

improving the gel. The treatment of the lime extract with potassium hydroxide and subsequent neutralization with hydrochloric acid was the easiest way of obtaining this product. A series of experiments was carried out on every part of this process to see whether alterations could be made which would improve the final gel.

Since the *Gigartina* used may vary from one batch to another (see p. 83 *et seq.*), a large quantity of weed was collected during the summer and autumn, air-dried and stored for experimental work. This stock had to be renewed once or twice but where results are compared in the tables they refer to a single batch of weed.

METHODS USED IN TESTING AGAR

A large number of tests have been suggested for estimating the quality of agar gels (see Kizevetter, 1937a). Since the chief aim of the work was to produce an agar which might replace imported agar for bacteriological purposes, the tests were chosen accordingly.

MELTING AND SETTING POINTS

Several of the methods available for testing the melting and setting points of gels were tried for agar. Agar does not adhere to glass and other surfaces as does gelatine and some methods were ruled out on this account. Hatschek's method (1925) of watching surface changes while cooling was not accurate enough. The method given by Kizevetter (1937a, pp. 116-117) of suspending a block of gel on a bent wire in an oil bath and noting the temperature at which the block falls off was inconvenient and inaccurate. Kizevetter, however, also suggests making a gel with included air bubbles and watching the temperature at which they begin to move or stop moving as the temperature of the whole is raised or lowered. This was the basis of the following method which proved quite satisfactory.

A small tube about 7.5 cm. long by 1 cm. diameter is filled with the melted agar solution and a rubber stopper inserted so as to enclose a small but easily visible air bubble. This is most easily done by putting in a thread along with the stopper, enclosing a small bubble, and withdrawing the thread as the stopper is pushed in. The agar is then allowed to set with the stopper downwards. When cold the tube or tubes are attached vertically by a rubber band to a plate which can be inverted in a well-stirred water-bath and the temperature gradually raised. As the melting point is approached the bubble becomes spherical and just leaves the bottom of the tube; at the melting point it rises rapidly to the top of the tube. To find the setting point the temperature is gradually lowered and at each degree or half-degree, according to the accuracy desired, the tube is inverted. At the setting point the bubble ceases to

move. It is difficult to make the bubble of uniform size and, as this was found to make a difference of a degree or two in the reading, other methods were tried. Lead shot and small steel balls were found to be too heavy and to break weak gels. Glass beads of about 2 mm. diameter were suggested as a substitute by Mr. B. A. Forder (of Messrs. Paines & Byrne, Pabryn Laboratories, Greenford, Middlesex), and proved very convenient. The concentrations of agar used for testing were at first 1%, 2%, 3%, 4% and 5% and later, when it was found that 2½% was the most suitable concentration for bacteriological work, 1%, 2%, 2½%, 3% and 4% were used. All five could be tested simultaneously.

SLOPE HOLDING AND SURFACE HARDNESS

About 5-10 ml. melted agar was poured into a test tube and allowed to set, with the test tube inclined at an angle such that the surface of the agar just reached the beginning of the curve near the bottom of the tube. It was left in this position overnight and then after standing it upright for half an hour it was transferred to an oven at 37-40° C. for 24 hours. Only those samples which showed no sign of slipping or cracking were considered satisfactory. The same concentrations as mentioned above were used.

About 10 ml. of agar was also poured into a small flat dish and allowed to set for several hours. The surface was then stroked or rubbed with a nichrome wire loop of British Standard Wire Gauge No. 23. If the surface tore readily the gel was considered unsatisfactory. This test is subjective and different bacteriologists use different kinds of wire loop so that more reliance was placed on the test for gel strength.

GEL STRENGTH

Of the methods of testing gel strength, that of Lipovitch (see Kizevetter, 1937a, p. 120) was tried; it depends on the breaking of the gel by a gradually

*Promising results were also obtained by treating the first extract with formaldehyde in the presence of alkali, either potassium hydroxide or lime, but these experiments were not followed up because better results were obtained with the treatment outlined above.

increasing weight. A cylinder of gel is prepared, and resting on this is a small hemispherical metal button attached by a rod to a horizontal plate which bears a cup. Mercury is run into the cup gradually and the weight at which the gel breaks is noted. It was found that the weight required to break the gel depended very largely on the rate at which the mercury was added, and also that an elastic gel, although actually weaker when measured by other methods, might sustain a greater weight of mercury than a strong gel.

The method of measuring gel strength described and figured by Campbell (1938) was considered more suitable and some preliminary tests with it were made through the kindness of Dr. T. McAra, then Director of the British Association of Research for the Cocoa, Chocolate, Sugar, Confectionery and Jam Trades. With slight modifications in the method Campbell's Jelly Tester proved very satisfactory. The agar to be tested is allowed to gel in a cubical metal box. A metal spade is inserted which is turned by pulleys through a small angle in the gel when water is added gradually to a suspended cup. The amount of water in ml. required to rotate the spade through a given angle in the gel, e.g. 30°, is measured and gives the strength of the gel. The instrument was intended for testing more elastic gels (e.g. pectin jellies) and therefore minor modifications had to be made. The amount of water measured was that required to turn the spade through 10° and 20° (instead of 30°) and the rate of flow was adjusted to 20-25 ml. per minute instead of 100 ml. per minute. All measurements were made on a 2% solution made up on a dry weight basis and allowed to stand overnight in a refrigerator at 0°-5° C. Freezing must be avoided.

PREPARATION OF AGAR FROM GIGARTINA AND CHONDRUS

DRYING, STORAGE AND BLEACHING OF WEED

Owing to the springy and cartilaginous nature of the thallus, *Gigartina* dries more rapidly than most seaweeds and can be dried to a water content of from 20-25% of the total weight by exposure on wire racks for a few days indoors. For prolonged storage more complete drying is desirable and if it is not kept in a dry place it will go mouldy. When dried to a very low water content it becomes brittle and breaks easily into small particles, which are more difficult to handle in the subsequent extraction. Water up to about 20% is in any case reabsorbed on storing (see p. 60).

An experiment was made to find the effect on the resulting agar of drying the weed at different temperatures. For this, samples were dried in a thermostatically controlled oven for 12 hours or more and the process carried through as usual. The results are shown in Table 10 and indicate that drying at a temperature of 100° C. or higher is injurious.

On storing, the colour gradually changes from the reddish-brown of the original mature weed to a pinkish-purple. It was found that extraction of the gel is easier

The measurements were done in duplicate, were made as quickly as possible and the temperature of the gel noted at the end. Agreement between duplicates was usually good. A gel strength of 200 or over for 20° deflection (or 150 or over for 10° deflection) was considered satisfactory.

SULPHATE

This was estimated by the method described by Butler (1936).

CALCIUM

The calcium was estimated after ashing.

CHLORIDE

Drechsel's modification of Volhard's method (Treadwell and Hall, 1924, p. 603) was used because it was found that on heating the dry agar, even at a gentle heat, some of the chloride was volatilized. After the silver nitrate had been added the solution was acidified and brought to boiling point in order to hydrolyse the agar.

VISCOSITY

This was determined in Standard U tubes (British Standard 188 : Anon., 1937). The measurement of the viscosity of gelling substances presents special difficulties. The viscosity changes with time of standing even although the temperature is several degrees above the setting point. With certain agars also, e.g. that from *Pterocladia*, part of the solution flocculates even at temperatures much above the setting point; this can be avoided by keeping the solution continuously in motion.

and more complete when the weed has been stored for some time; the quality of the product is also improved. For example, *Gigartina* collected in September and extracted within a fortnight, gave gel strengths of 166 and 270 for 10° and 20° deflection respectively. When stored until December and a similar extraction made, the gel strength had risen to 211 and 323 respectively (see Table 17, p. 85). In addition the yield in the two extractions made had risen from 35% to 51% of the dry weight of the weed. Further results on storage are given on p. 83.

An attempt was made to hasten this maturing by drying the freshly collected weed at a temperature of 80° C. When agar from this weed was compared with that from the same weed dried in the ordinary way, it was found that although the yield had not increased appreciably, the gel strength was considerably improved. At present no explanation of this phenomenon can be offered.

The weed can be bleached by exposure to the air but it is a slow and uncertain process, since *Gigartina* bleaches much less rapidly than *Chondrus* and excessive

exposure of the harvested weed in the open air in wet weather results in a loss of gelling substance.

In the hope that a less coloured extract would be obtained, rapid bleaching of the seaweed by artificial means was tried. The damp weed can be easily bleached with sulphur dioxide but the colour tends to return on exposure to the air and the extract with lime is then as much coloured as the normal. If the sulphur dioxide is left too long in contact with the damp weed the resulting gel is poor, indicating that the acid sulphur dioxide has hydrolysed the gelling substance. Bleaching with chlorine gas is altogether too violent and breaks down the weed; the resulting gel is very weak.

Extraction with calcium hypochlorite instead of lime does not give a colourless extract.

Since with both bleached and unbleached weed the potassium hydroxide treatment produces a deep yellow colour which has to be removed at a later stage, it was decided that initial bleaching of the weed was unnecessary.

WASHING

Haas and Hill (1921) distinguished between the extract obtained from *Chondrus* by washing the weed with cold water and that obtained by extracting the washed residue with hot water. They found that the effect of Rochelle salt on the gelling power was much more marked with hot water extract than with cold water extract.

It was found that washing *Gigartina* overnight in running water led to an improvement in the quality of the final product. When heated with lime the extract was less coloured and although more viscous did not set to a gel. After potassium hydroxide treatment however the gel was improved in that it was harder and the melting and setting points were lower, both desirable properties from the bacteriological point of view.

A series of experiments made on the effectiveness of washing the weed in different ways showed (Table 11) that instead of washing in running water overnight, which is wasteful on a large scale, the same result could

be achieved by rinsing several times. This was done by stirring the weed thoroughly with a large volume of water, allowing to stand 10 minutes, and then draining. The washing water was usually coloured pinkish but in addition it must have carried away the adhering or readily diffusible salts which would have tended to raise the melting and setting points. Another advantage of initial washing or rinsing is that the strips of dried agar do not adhere to the drying plates (see p. 83) as they do when the seaweed is unwashed.

If the seaweed is washed while still living (i.e. immediately after collecting), the washing does not have the same effect and an extract made subsequently has the undesirable qualities of that from the unwashed weed (see Table 11). Two of the experiments in this table were done at a time of year when the seaweed yields only a poor quality gel (see p. 83) and after it had been stored for only a short time, both of which factors account for the very low extraction and the softness of the gel.

The loss of soluble substances from the weed during washing was investigated. Two preliminary experiments were made in both of which the weed, after rinsing under the tap for a few moments to remove adhering salts and dirt, was washed for 24 hours in running water, but these gave discordant results. Two further experiments were then made; in the first of these the dried weed was not rinsed, in the second the weed was rinsed for a few moments immediately after collection while still living and was then dried and stored for three weeks. The moisture content of the weed was estimated and samples were weighed out and put in open-ended glass cylinders, one end of each of which was closed by fine muslin. The cylinders were then put in a tank, the lower closed end raised clear of the bottom, and a continuous current of water run through each cylinder. After washing in this way for different lengths of time, the cylinders were removed, the weed was collected and dried to constant weight, and the loss calculated.

The results (Text-fig. 35 and Table 21, p. 92) show that the maximum loss occurs in the first fifteen minutes

TABLE 10

EFFECT OF DRYING WEED AT DIFFERENT TEMPERATURES

TIME OF DRYING*	TEMP. OF DRYING °C	MELTING POINT °C.					SETTING POINT °C.					HELD SLOPE %	HARD ENOUGH %	JELLY TEST		Cl %	YIELD %
		1%	2%	2½%	3%	4%	1%	2%	2½%	3%	4%			10°	20°		
Air-Dried		40	51	54	57	60	24	32	35	38	42	2½	2½	177	279	4.8	29
22 hrs.	80	38	50	53	55	60	24	34	36	37	48	3	2½	164	257	3.8	37
17 "	90	40	50	54	56	60	25	34	37	39	44	2½	2½	196	259†	4.2	37
17 "	100	38	48	52	54	58	22	32	35	37	42	3	2½	131	180	3.7	37
	110	31	44	48	51	56	20	32	36	38	43	3	2½	100	126	3.8	36
	120	39	47	50	53	58	22	33	36	39	44	3	3	112	155	4.1	38

*Stock B weed used.

†Gel broke before 20°.

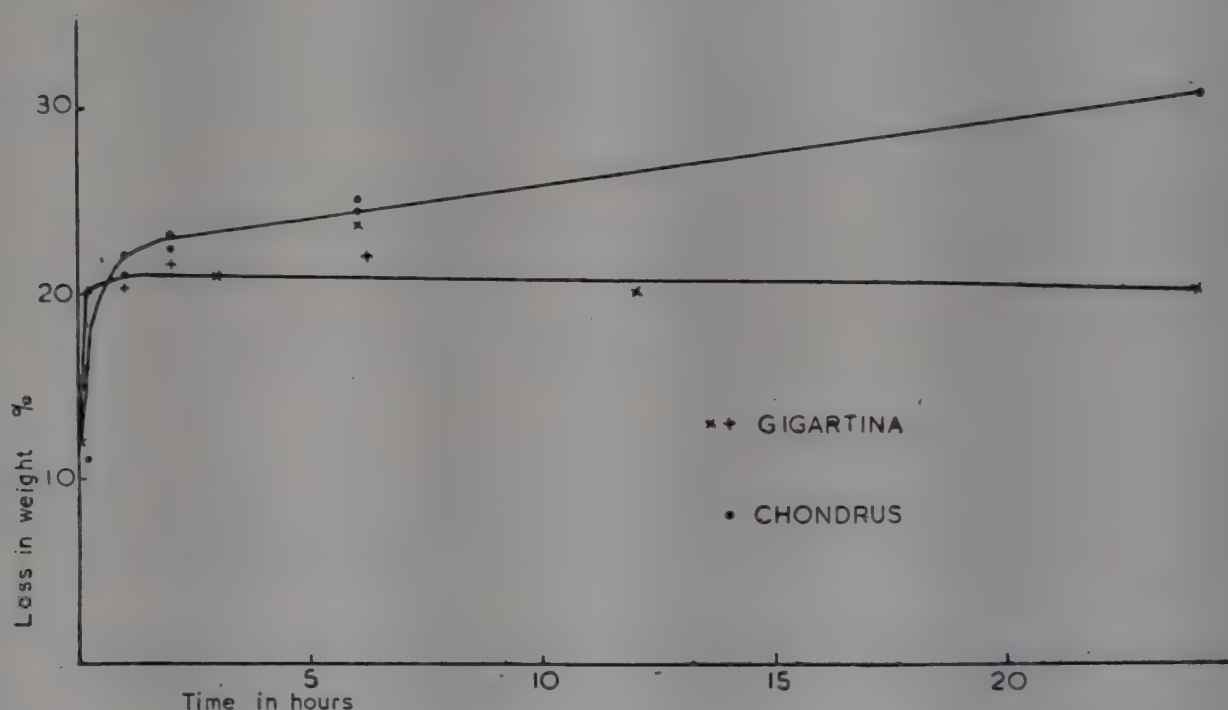
and that there is very little loss thereafter. This is confirmed by the ash content which shows a rapid fall from an initial value of 18.12% to 11.90% after 10 minutes washing. Ash value then remained fairly constant with a gradual rise as the gel was washed away. The first eight experiments in Table 11 show that to give gels of maximum strength a longer period of washing is necessary than that suggested by the above experiments, and some further experiments were done to check this point. They confirmed the fact that fifteen minutes thorough washing, although it improves the final gel, is decidedly less effective than a continuous washing of three hours or longer. The details are shown in the lower part of Table 11. As before, the setting points of the gel from the washed weed are slightly lower than those of the unwashed.

The lime extract from the washed weed is more viscous than that from the unwashed, and this is probably

greatly but with high proportions of weed it becomes increasingly difficult to screen off the more and more viscous liquid from the weed. With low proportions of weed the final concentration is very low and the gel consequently difficult to dry. In the laboratory a suitable proportion is one part by weight of air-dried weed to 30 of water.

The viscosity of this first extract varies considerably and this may be related to seasonal changes in the weed. These changes however, if present, are masked by the variations which occur with slight alterations in heat treatment.

The effect of varying amounts of lime is shown in Table 12. When account is taken of the amount of lime added there is no appreciable increase in the yield and when there is more than 3% (on the weight of the weed) the melting and setting points of the final product are raised. The gel strength rises with increasing lime.



TEXT-FIG. 35

Loss of weight on washing Gigartina and Chondrus

due in part to the removal of salts since, on making up the extract from the washed weed in 0.5% potassium chloride, the viscosity is again reduced (Text-fig. 36). It was found that the viscosity is altered considerably by heating the extract and that the longer it is exposed to high temperatures the lower the viscosity falls. When similar extracts are made from Gigartina and from Chondrus, the viscosity of that from Chondrus is usually higher.

EXTRACTION

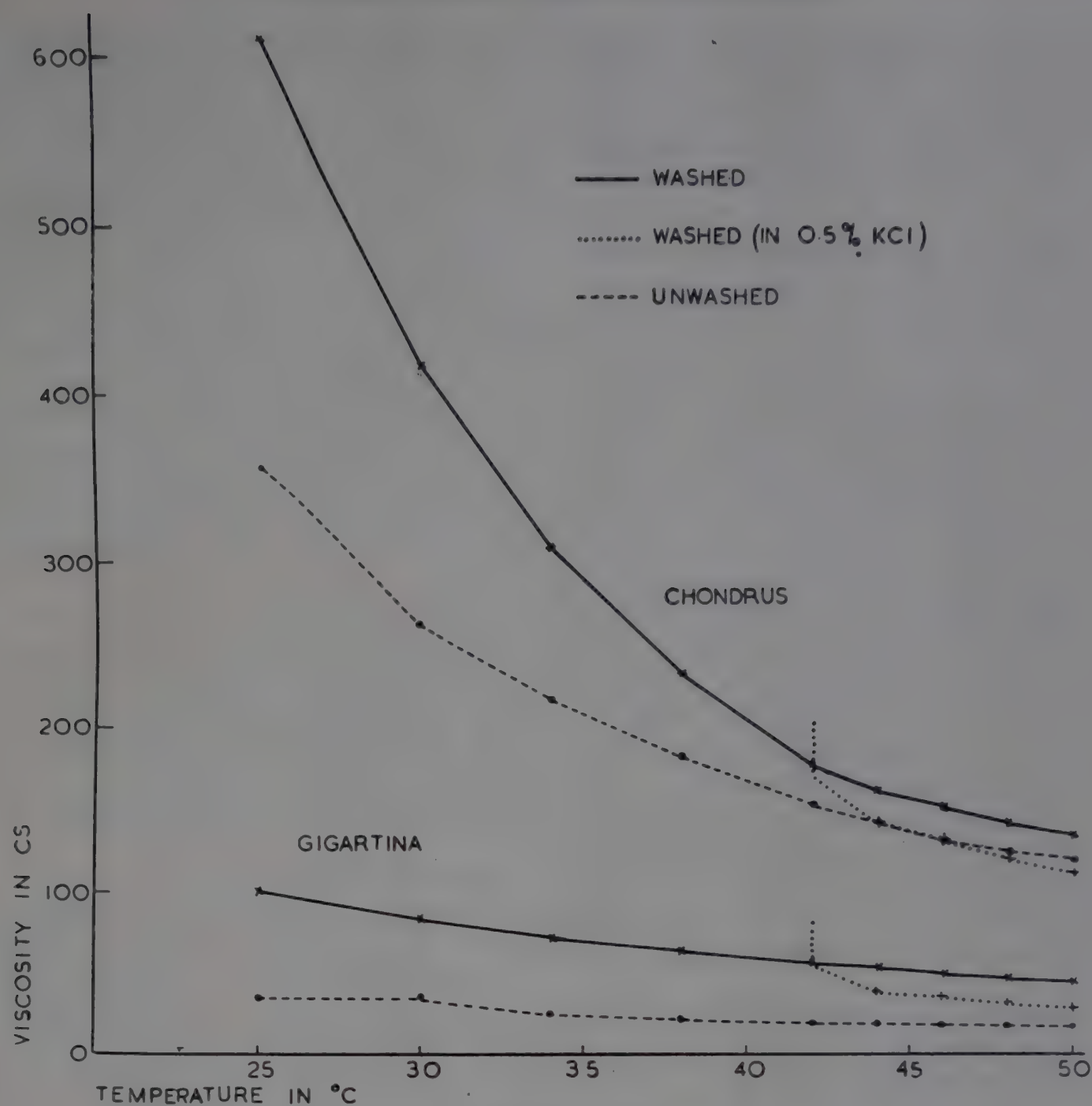
Gigartina can be extracted by water alone but if there is any acid developed (as may happen when it is extracted under pressure) hydrolysis takes place and the gelling power is lost. The addition of a small quantity of lime not only prevents hydrolysis but also improves the colour of the extract.

The proportions of weed to water can be varied

About 2-3% of lime on the weight of the air-dried weed was found to be convenient in laboratory practice. An experiment was made using a small quantity of potassium hydroxide instead of lime to prevent hydrolysis. The yield of the first extract was much the same but the agar made from it was dark coloured and the gel elastic and not so strong as usual.

The weed can be extracted either with or without pressure. Extraction in an autoclave at a pressure of 4-5 lbs./sq. in. gave a slightly improved yield. When a higher pressure is used (e.g. 10 lbs./sq. in.) the final agar changes in character and becomes more viscous. The yield in a single extraction varied between 15% and 50% of the original dry weight of the weed (see p. 71).

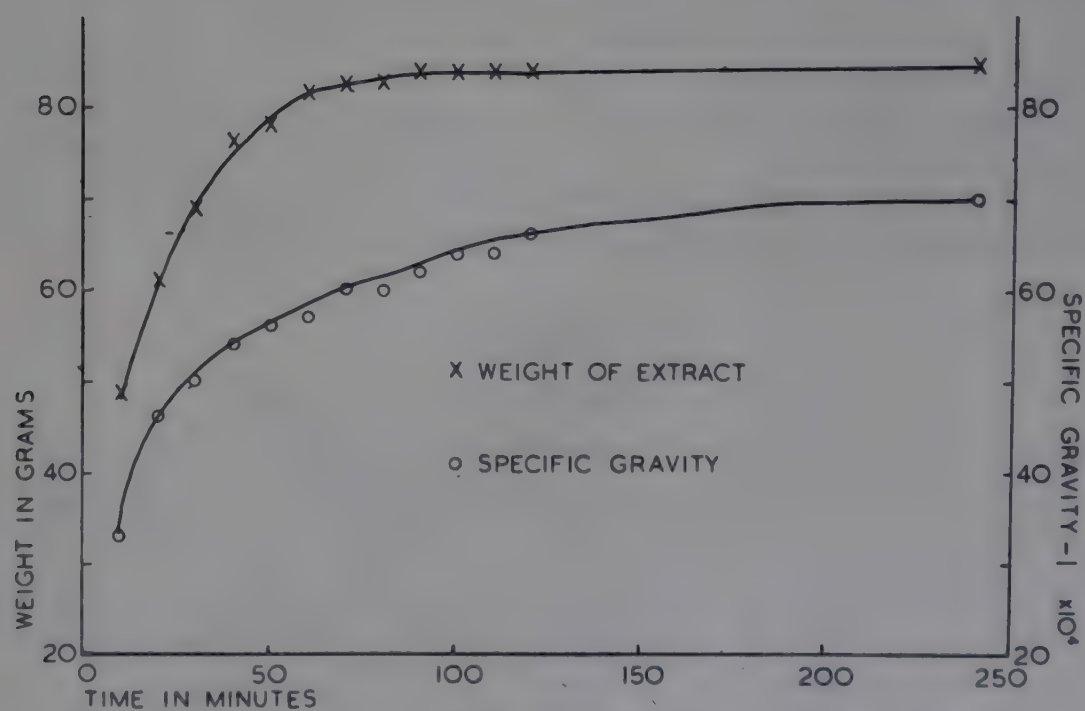
An experiment was made to find the rate at which the weed yielded its extract on heating at 100°C. 200 gm. of weed (22% moisture) was washed and put into



TEXT-FIG. 36

Viscosities of the lime extracts of Gigartina and Chondrus in 1% solution

(Based on data contained in Table D in the Ministry of Supply Permanent Record Monograph No. 11,145)



TEXT-FIG. 37

Rate of extraction of Gigartina

(Based on data contained in Table E in the Ministry of Supply Permanent Record Monograph No. 11,145)

first extraction, nearly 20% in the second, 4% in the third and only 2% in the fourth. Since more than 20% of the desired material is left after the first extraction it seemed possible that a better yield could be obtained by (1) a counter-current method or (2) further treatment of the residues:

(1) 100 gm. weed (a) was extracted with 4 litres of water and gave a yield of 32 gm. of solids. The residue was extracted with a further 4 litres of water and the filtrate contained 10 gm. of solids. A further 100 gm. of fresh weed (b) was extracted with 4 litres of filtrate from the second treatment of (a) and yielded 34.6 gm. of solids instead of the expected 42 gm. The residue from (b) was further treated with 4 litres of water and the filtrate contained 9.8 gm. solids. This filtrate was used for extracting a third batch of weed (c) and yielded only 37 gm. solids. Although there is therefore a slight increase in the amount extracted, it is less than half the theoretical value and this is not good enough to justify the adoption of the method.

(2) The residues from three successive lots of seaweed were put together and re-extracted. The yield was low probably because not enough water was used. The extract from the residues was used for the preparation of agar and in Table 13 (ii) its quality is compared with that of a normal (first extraction) agar, Table 13 (i), from the same weed. It is obvious that the quality of the agar from the second extraction is much below that of the first.

A further experiment was made to find out if the quality of the agar produced in the first few minutes of the extraction was superior to the rest. For this purpose, extraction was stopped after the first 20 minutes and the weed screened off. The residue was then re-extracted for two hours. The process was completed on each of the two fractions and the quality of the resulting agars is shown in Table 13 (iii and iv). Although the agar from the first 20 minutes boiling is better than that from the subsequent boiling, it is no better than that from 1½ hours extraction and therefore no modifications were made in the method.

It is necessary to know the exact strength of the extract before treatment with potassium hydroxide. In

the early experiments it was assumed that the amount extracted was one third of the weight of the weed used and potassium hydroxide was added accordingly. These experiments are marked with an asterisk in the tables. Later the exact amount was estimated by evaporating a known weight of the first extract and drying to constant weight at 105° C. Since this is time-consuming, it was hoped that there would be a constant relation between specific gravity and percentage of solids. The results of a large number of concurrent determinations of both are shown in Text-fig. 38. The deviations from a straight line are, however, too great for this method to be satisfactory. One cause may be that the viscous extract usually contained small air bubbles which are difficult to get rid of, and also small particles of seaweed which have come through the muslin.

POTASSIUM HYDROXIDE TREATMENT

Although the treatment with potassium hydroxide improved the gel considerably, it was still much softer than Japanese agar and experiments were made to improve it, both by varying the quantity and concentration of potassium hydroxide and by varying the heat treatment to which it was subjected.

Amount of Potassium Hydroxide

When the first experiments were made (see Table 14) there was no accurate means of measuring the gel strength. Quantities of potassium hydroxide varying from about 15% to 30% of the dry weight of the extract were added and the mixture was heated at boiling point for about an hour, neutralized, filtered, and dried as usual. The melting and setting points of the resulting agar were increasingly higher and there was a slight improvement in slope-holding capacity. These agars were submitted for testing to J. MacNaughtan of the Bacteriological Department, Edinburgh University, and she preferred those prepared with 20% and 25% of potassium hydroxide because of their increased hardness. The raised setting points were, however, an inconvenience to other bacteriologists (see Appendix I).

After pressure treatment had been found to improve the gel hardness greatly (see below) some experiments

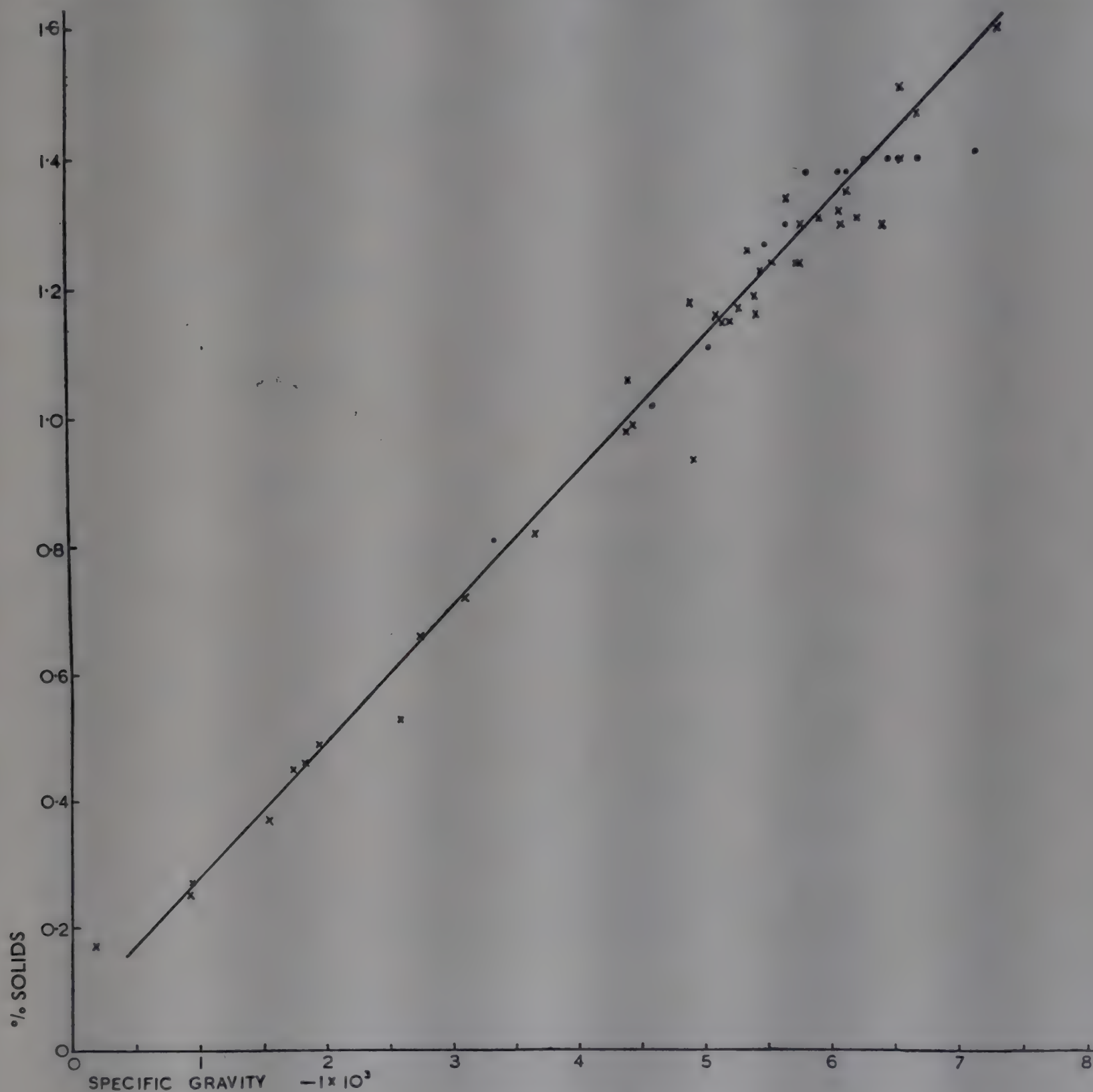
TABLE 13
QUALITY OF AGAR FROM RESIDUES*

	MELTING POINT °C.					SETTING POINT °C.					HELD SLOPE IN %	HARD ENOUGH IN %	JELLY TEST		Cl %
	1%	2%	2½%	3%	4%	1%	2%	2½%	3%	4%			10°	20°	
(i) First extraction	45	57	60	62	66	27	36	38	41	46	2	2	203	309	4.1
(ii) Residues extracted....	41	52	57	59	63	24	34	37	39	44	2½	3	88	117	5.9
(iii) First 20 mins. extraction	39	51	55	57	60	23	32	35	37	41	2½	2	199	304	3.5
(iv) Residues from above	38	49	53	55	60	22	31	34	37	41	3	2	169	245	2.9

*Stock C weed used.

were made to see if the potassium hydroxide could be decreased without harm. Concentrations from 15% (the usual) down to 5% were tried and the results are shown in Table 14. A reduction to 12.5% makes little difference but a reduction to 10% lowers the gel strength considerably and to 5% makes it still worse.

hydroxide and several experiments were made with extracts varying from 3.6% to 4.4% instead of the usual 0.8% to 1.3%, using the same proportion of potassium hydroxide to dry extract (15%). This increased concentration, however, did not effect any improvement (see Table 15, double extraction).



TEXT-FIG. 38

The relation between specific gravity and percentage of solids in the lime extract of Gigartina

* Results from experiments summarised in Table E in the Ministry of Supply Permanent Record Monograph No. 11,145.

x Results from normal extractions.

Reducing the potassium hydroxide also lowers the melting and setting points and reduces the slope-holding capacity.

Concentration of Potassium Hydroxide

It was thought that a more concentrated extract might be more readily acted on by the potassium

Variation in time and temperature of treatment

The potassium hydroxide treatment was initially carried out in an autoclave where a maximum pressure of only 5 lbs./sq. in. could be obtained. Numerous experiments were made at 0 and 5 lbs. pressure for times varying up to 36 hours. With times up to 5 hours, the results were not clear although they suggested that

TABLE 14

EFFECT OF VARYING POTASSIUM HYDROXIDE AND PRESSURE

DATE	AMOUNT KOH. % ON SOLIDS	TREATMENT		MELTING POINT °C.						SETTING POINT °C.						HELD SLOPE IN %	HARD ENOUGH IN %	2% JELLY TEST		Cl %	NOTES
		HRS.	PRES- SURE LBS./ SQ. IN.	1%	2%	2½%	3%	4%	5%	1%	2%	2½%	3%	4%	5%			10°	20°		
				1%	2%	2½%	3%	4%	5%	1%	2%	2½%	3%	4%	5%						
18. 3.42	15*	1	0	—	47	—	52	56	60	—	29	—	36	40	44	4	3	—	—	—	Stock A weed ; bleached.
28. 4.42	20*	1	0	36	51	—	59	61	64	19	32	—	39	43	46	4	3	—	—	—	Stock A weed.
6. 5.42	25*	1	0	44	56	—	62	66	70	24	37	—	43	48	52	3	3	—	—	—	"
9. 6.42	25*	1	0	44	52	—	60	64	67	29	38	—	44	48	52	2	2	—	—	—	"
16. 6.42	25*	1	0	—	46	—	58	64	69	—	35	—	42	48	52	3	3	—	—	—	"
23. 6.42	15+10%* as KCl	1	0	45	53	—	60	65	67	22	37	—	44	48	52	3	4	—	—	—	KCl added after neutraliza- tion. Stock A weed.
10. 6.42	27.5*	1	0	39	53	—	60	64	68	23	37	—	44	48	52	3	3	—	—	—	Stock A weed.
11. 6.42	30*	1	0	35	51	—	59	65	69	21	40	—	46	50	54	3	4	—	—	—	"
12.10.42 III	8*	½	20	29	44	—	50	54	60	13	26	—	31	35	51?	4	4	—	—	4.0	"
12.10.42 I	15*	½	20	39	50	—	56	62	64	20	34	—	39	43	47	3	3	76	104	5.0	"
13.10.42 I	40*	½	20	44	58	—	66	71	75	33	43	—	51	55	59	2	3	—	—	14.3	"
3.11.42 II	15*	1	40	40	51	—	57	62	65	25	36	—	42	46	50	3	3	—	—	6.5	"
3.11.42 I	30*	1½	40	40	53	—	61	64	70	27	41	—	47	52	56	2	3	—	—	10.4	"
25.10.43	5	2	40	30	40	44	49	52	—	<15	22	25	30	31	—	>4	>4	60	70	1.4	Stock C weed.
15.10.43	10	2	40	37	49	52	55	61	—	21	30	33	43	45	—	3	2½	175	273	2.4	"
1.11.43	10	2½	40	32	46	51	53	57	—	18	27	30	33	37	—	3	4	86	124	0.8	"
11.10.43	12	2	40	40	54	57	60	63	—	23	32	36	38	42	—	2	2	194	300	3.4	Extracted by counter cur- rent method with residue fluid. Stock C weed.
1.10.43	15	2	40	45	57	60	62	66	—	27	36	38	41	46	—	2	2	203	309	4.1	Stock C weed.
9.12.43	12.5	2	40	40	50	54	56	60	—	23	31	35	37	41	—	2½	2	201	305	3.5	Stock B weed.
18.11.43	15	2	40	40	51	54	57	60	—	24	32	35	38	42	—	2½	2½	190	297	4.8	"

*Calculated on the assumption that the yield was one-third of the weight of the weed used.

TABLE 15
EFFECT OF PRESSURE ON POTASSIUM HYDROXIDE TREATMENT:
STOCK A WEED

DATE	% KOH ON WT. OF SOLIDS	TREATMENT		MELTING POINT °C.						SETTING POINT °C.						HELD SLOPE IN %	HARD ENOUGH IN %	2% JELLY TEST		CI %	NOTES
		HRS.	PRES- SURE LBS./ SQ. IN.	1%	2%	2½%	3%	4%	5%	1%	2%	2½%	3%	4%	5%			10°	20°		
				mins.	mins.	mins.	mins.	mins.	mins.	mins.	mins.	mins.	mins.	mins.	mins.			mins.	mins.		
4. 8.42	15*	1	0	32	49	—	54	61	64	15	32	—	38	44	48	4	4	25	34	7.8	Pressure cooker.
10. 9.42	15*	24	4-5	34	51	—	58	63	67	26	36	—	43	47	50	3	3	129	205	4.3	
10. 9.42	15*	36	4-5	33	49	—	56	62	65	23	39	—	43	47	52	3	3	133	Broke	2.6	
17.11.42	15*	10	20	33	48	—	55	59	64	22	33	—	38	43	48	3	3	67	94	5.6	
12.10.42 I	15*	½ hour	20	39	50	—	56	62	64	20	34	—	39	43	47	3	3	76	104	5.0	Pressure extraction. Double extraction.
11.12.42 I	15	2	20	38	48	—	54	57	58	22	32	—	37	41	42	3	3	110	127	4.9	
18.12.42	15	2	20	37	52	—	58	64	68	27	39	—	43	47	52	3	2	147	217	7.3	
10.11.42	15*	3	20	42	53	—	57	60	65	24	34	—	39	44	47	3	3	131	Broke	5.8	
9.12.42	15	4½	20	36	47	—	54	59	62	24	32	—	39	43	48	3	3	156	240	4.7	Double extraction. Double extraction.
14.12.42	15	4½	20	41	53	—	57	63	66	28	37	—	42	47	54	2	3	165	245	6.6	
22.12.42	15	8	20	38	50	—	56	60	63	25	35	—	42	45	48	2	3	156	228	4.9	
14. 1.43	15*	8	20	40	48	—	54	58	61	24	33	—	38	42	49	3	—	168	221	4.6	
13. 3.43	15	8	20	35	48	50	54	59	—	23	34	37	39	43	—	3	2½	138	219	3.7	
9. 3.43 II	15	15	20	30	45	47	50	56	—	19	30	33	36	39	—	3	2½	126	169	2.1	
3.12.42	15*	24	15-20	31	44	—	54	58	62	21	33	—	38	43	48	3	3	141	179	4.0	
11. 3.43 I	15	24	20	33	47	51	54	58	—	23	34	37	39	43	—	2½	2½	158	233	3.5	
11. 3.43 II	15	36	20	31	44	48	52	56	—	18	33	37	39	44	—	3	3	139	203	2.4	
9. 3.43 I	15	½	40	30	45	48	51	58	—	18	29	33	36	39	—	2½	2½	105	137	3.8	
2. 3.43	15	1	40	33	47	50	53	57	—	24	34	36	38	43	—	2	2	136	212	4.1	
15. 3.43 III	15	1	40	37	50	53	56	61	—	24	34	38	40	46	—	2	2½	151	233	4.2	
23. 3.43 I	15	1	40	40	50	53	56	60	—	24	34	38	41	45	—	2	2½	155	246	5.2	
15. 3.43 II	15	2	40	42	52	54	58	62	—	26	35	38	40	46	—	2	2½	210	323	5.2	
3. 3.43	15*	3	40	36	49	52	56	59	—	25	34	37	40	44	—	2½	3	149	231	4.6	
15. 3.43 I	15	4½	40	39	50	53	57	60	—	24	34	38	40	45	—	2	3	120	158	4.9	
9. 3.43 III	15	6	40	27	40	43	47	52	—	<15	30	32	35	39	—	4	3	42	49	1.5	

*Calculated on the assumption that the yield was one-third of the weight of the weed used.

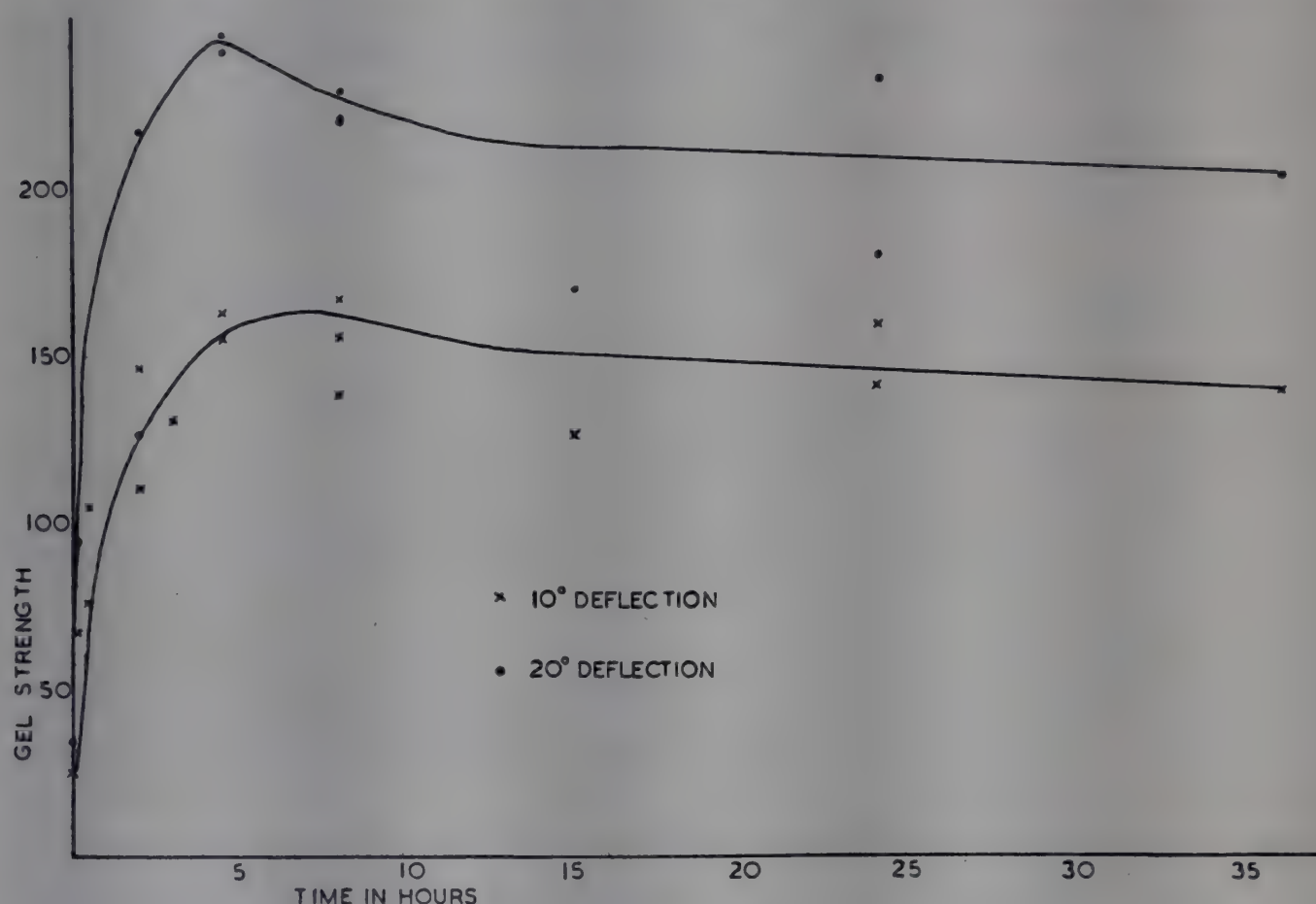
slope-holding capacity was slightly increased. At this stage however no accurate means was available for measuring the strength of the gel formed. With one experiment in which the treatment was carried on for 24 and 36 hours the improvement in gel strength was recognisable even by touch, and when measured at a later date it was found to have increased from 25 and 34 (for 10° and 20° deflection respectively) when no pressure was used, to 129 and 205 after 24 hours' treatment. There was a slight further rise after 36 hours' treatment, and also a slight rise in melting and setting points (see Table 15).

A series of experiments was then carried out in a small pressure cooker in which only about one litre could be treated at a time. The results showed (Table 15)

the rate of heating up the autoclave. Because of the tendency of some gels to break at 20° deflection, the 10° deflection figure gives the more reliable comparison. The melting and setting points showed little or no change.

At a pressure of 40 lbs./sq. in. (Text-fig. 40) the maximum gel strength attained was higher and was reached after only two hours. Beyond this there was a rapid deterioration in the gel and with 6 hours the strength was seriously reduced. Melting and setting points were little affected except after 6 hours when there was an abrupt fall in both; the slope-holding capacity had also been reduced.

Samples of agar made with and without pressure treatment were freed from electrolytes by dialysing against repeated changes of distilled water for three



TEXT-FIG. 39

Effect on gel strength of autoclaving at 20 lbs./sq. in. (Gigartina)

that a treatment at high pressure did improve not only the strength of the gel but also its slope-holding capacity. The melting and setting points did not seem to be altered by times and pressures up to 3 hours at 45 lbs./sq. in.

A larger autoclave was then obtained which would give a pressure up to 60 lbs./sq. in. and a further series of experiments was made to find the optimum time at different pressures. The results are shown in Table 15 and Text-figs. 39 and 40.

At a pressure of 20 lbs./sq. in. (Text-fig. 39) the gel strength rises rapidly for the first 4 to 5 hours after which there is a small and gradual fall. The points in Text-fig. 39 do not lie on a smooth curve and repetitions of the experiment do not give identical results but this may be on account of variations in pressure and in

days, and then dried, when they contained only a trace of chloride and had only weak gelling properties. They were then made up in 1% potassium chloride and the gel strengths compared. Those for the non-pressure-treated sample were 43 and 51, for 10° and 20° deflection respectively, whereas for the pressure-treated agar they were 260 and 415. Therefore, quite apart from the added electrolytes there is a very marked change produced in the agar by pressure treatment.

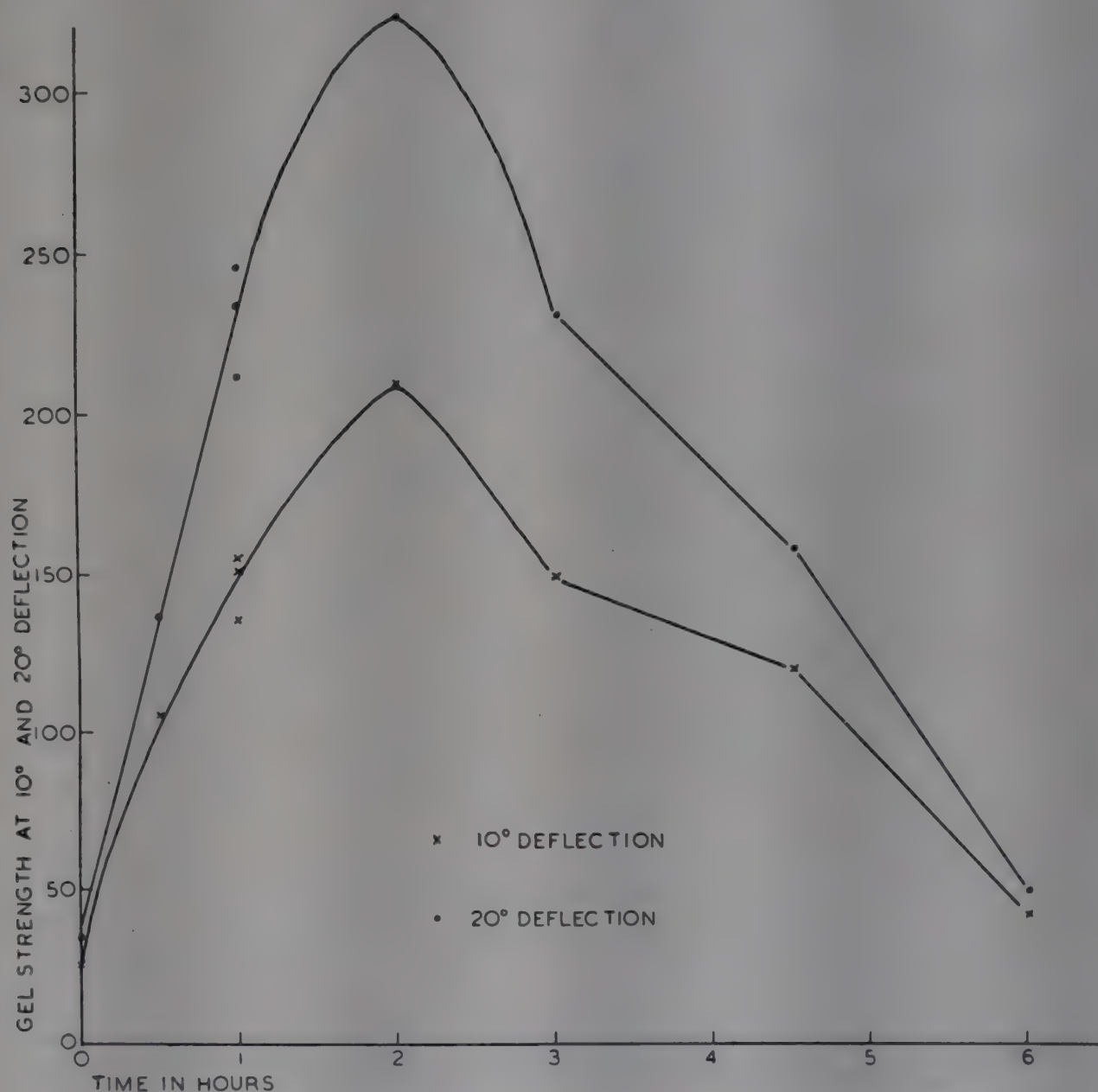
Pressure treatment did not reduce the sulphate content of the agar though, as Haas and Russell-Wells (1929) have shown, some would be changed from the organic to the inorganic form.

Experiments were made using caustic soda or barium hydroxide instead of caustic potash but although some hydrolysis took place neither of these gave good products.

Neutralization

This was effected by the gradual addition of dilute hydrochloric acid. Thorough stirring is necessary because the formation of strongly acid pockets would destroy part of the gel. The pH value was measured by removing a few drops, mixing with an indicator in a small test tube and cooling. B.D.H. universal indicator was used first and then as neutrality was approached, brom thymol blue. The addition of acid was stopped at about pH 7. The agar solution was yellowish-brown and contained a slight precipitate, but the colour could

An interesting result of the pressure treatment is that the more severe the treatment, the less acid is needed to neutralize the agar and consequently the lower the percentage of chloride in the final product. This suggests that during the alkaline hydrolysis there is a production of acid. Haas and Russell-Wells (1929) in an attempt to isolate the carbohydrate residue by alkaline hydrolysis of the cold water extract found that, as well as partly removing the sulphate group, it produced among other substances, lactic acid. It would not have been expected, since hydrolysis is taking place, that



TEXT-FIG. 40

Effect on gel strength of autoclaving at 40 lbs./sq. in. (Gigartina)

be matched against a colour chart (Clark, 1928) without much difficulty.

On one occasion sulphuric acid was used for neutralizing instead of hydrochloric acid and was equally effective. The gel strength of the resulting agar was as high and the melting and setting points much the same as a comparable sample neutralized with hydrochloric acid. The percentage of chloride was only 0.28% as against the normal 4-5%. The result agrees with the earlier finding (pp. 66-67 and Text-fig. 32) that potassium sulphate is almost as good as potassium chloride in improving the gel.

heat treatment under pressure would have increased the gel strength. Acid hydrolysis, for example, destroys the gelling power very rapidly.

DECOLORIZATION AND FILTRATION

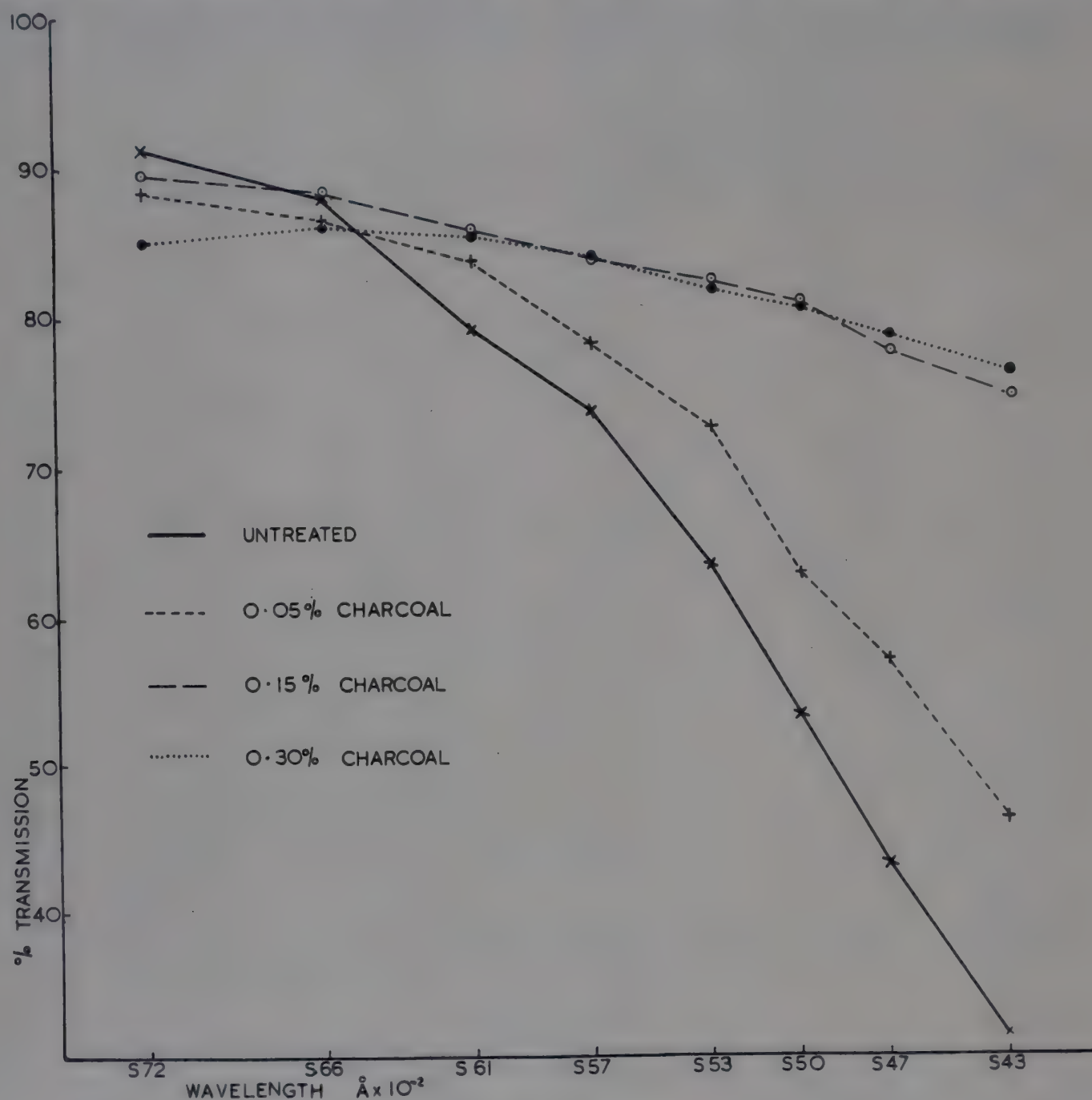
After neutralizing, the agar treated with potassium hydroxide had a yellowish-brown colour and it was desired to improve its appearance by removing this. Slight decolorization occurs on filtering through kieselguhr but effective decolorization was achieved only by treatment with activated charcoal. Some brands of charcoal are unsuitable because after treatment the

dried agar does not reconstitute completely and contains a white insoluble residue. Two brands however were found to be quite satisfactory, Merck's animal charcoal and Actibon S Neutral Grade (from Messrs. Perry and Hope, Paisley).

Some experiments were made to find the quantity of the latter required for the most efficient decolorization. Three concentrations were used, 0.05%, 0.15% and 0.30% on volume and a solution of about 1.3% of

Table 22 (p. 92) and those after 15 minutes boiling in Text-fig. 41. The absorption coefficients can be calculated by correcting for the absorption of the distilled water (Cooper and Milne, 1938, 1939). Compared with distilled water, the absorption of untreated agar solutions is high in the blue and violet.

0.05% Actibon is too little, 0.15% completes its effect in 15 minutes boiling and gives good decolorization, 0.30% is similar. In practice 0.15% Actibon



TEXT-FIG. 41

Percentage transmission of light through *Gigartina* agar compared with distilled water.
Treatment with varying amounts of charcoal for 15 minutes

agar* was first shaken with the charcoal and then boiled for varying times (5, 10, 15 and 30 minutes). It was then filtered through a rapid filter (Whatman No. 41), the first 10 ml. being refiltered. Filtration was probably not perfect since at the red end of the spectrum absorption was slightly increased as compared with untreated agar. The percentage of light transmitted by a 1 cm. column of the agar as compared with distilled water was measured in a Pulfrich photometer using a series of spectrum filters. The results are shown in

was mixed in after neutralization and the whole heated for half an hour at boiling point.

Filtration was best achieved under slight suction in a Buchner funnel (with a hot-water jacket) containing layers of sand and filter pulp over a No. 1 Whatman filter paper. Keiseluhr was also tried but choked rapidly.

DRYING AND GRINDING

In drying Japanese agar, the gel is cut into strips,

*The agar was made from *Chondrus*, but similar results are obtained from *Gigartina*.

frozen, and allowed to thaw. The thaw water carries away a large proportion of the impurities and the spongy residue dries readily in warm air. If strips of *Gigartina* agar are frozen and allowed to thaw, the gel does not retain a honeycomb structure as it does with Japanese agar and when it thaws the strips re-imbibe a considerable quantity of the thaw water. Some of the electrolytes are lost however and this tends to lower the melting and setting points. Neither could the filtered agar be dried by evaporation on the water bath because it adhered strongly to the container and even removed the surface from porcelain dishes. The agar was therefore allowed to gel, cut up in thin strips and dried in a current of warm air. In the early experiments the strips were laid on trays covered with muslin, but this was not satisfactory because it was sometimes difficult to remove them and they always retained small threads from the muslin. Eventually sheets of tin plate were used but even on them the strips tended to stick, especially if the seaweed had not been washed. This however was prevented by rubbing the plates with a few drops of a solution consisting of 45 gm. beeswax dissolved in a litre of turpentine mixed with a litre of benzol.

Agar chars readily and to find the highest temperature at which it could safely be dried, a series of experiments was made in which small quantities of the dry agar were heated for 12 hours in a thermostatically controlled oven at temperatures varying from 60-120° C. To give comparable results the agar solutions for testing were made up on a dry weight basis. The results are shown in Table 16 and indicate that drying can be carried out safely at least as high as 90° C. The harmful effect is not great even at 110° C. but at 120° C. the agar chars.

An alternative method is spray drying and a small sample was kindly dried in this way for us by K. Bullock of the Pharmacological Department, University of Manchester. A laboratory model spray drier was used and the product was satisfactory and re-constituted well.

Drying was also tried on a Mitchell laboratory model roller-drier but in this case the temperature rose too high and the agar lost its gelling power.

The agar strips when dry can be easily ground into a powder in an ordinary coffee mill. This powder is hygroscopic and should be kept in an air-tight container.

SEASONAL VARIATION IN GIGARTINA EXTRACTS

Most of the preceding experiments were done with stocks of weed which had been collected in summer or autumn and stored for some time. In April when the new fronds were growing and when papillae were fewer in number, a sample of *Gigartina* was collected from a spot which was known to have been harvested the previous year and an extract made at once. Both the yield of extract and the quality of the gel were low. This result was confirmed by a second collection and the weed was then stored for over 3 weeks, by which time the fronds had turned pink, and another extraction was made. There was an improvement in the yield and the quality of the gel was also better. Another extraction of weed collected in April was done eight months later when the yield showed a slight further improvement and the gel strength was much the same.

A collection was also made in April from a site which had not been harvested before and which had a larger proportion of papillated fronds. The yield was higher than that from plants collected at about the same date from an area showing much new growth and the quality of the gel was also better. About three weeks later when the dried fronds had turned pink, another sample of the same weed was treated. There was no improvement in the yield but the gel strength had increased considerably. As has already been shown (p. 71) an improvement in the gel also occurs in stored weed. The results of these extractions are shown in Table 17.

Since there was a considerable difference in the quality of the weed collected in April and in autumn, samples were collected monthly throughout the year to find the annual variation in yield and in quality of gel. To make the samples comparable they were all stored for at least three months before the extraction was made. The results are shown in Table 23 (p. 93) and the variations in gel strength in Text-fig. 42. There was no significant change in the melting and setting points of agar from weed gathered throughout the year, nor did the yield from two extractions show any important

TABLE 16

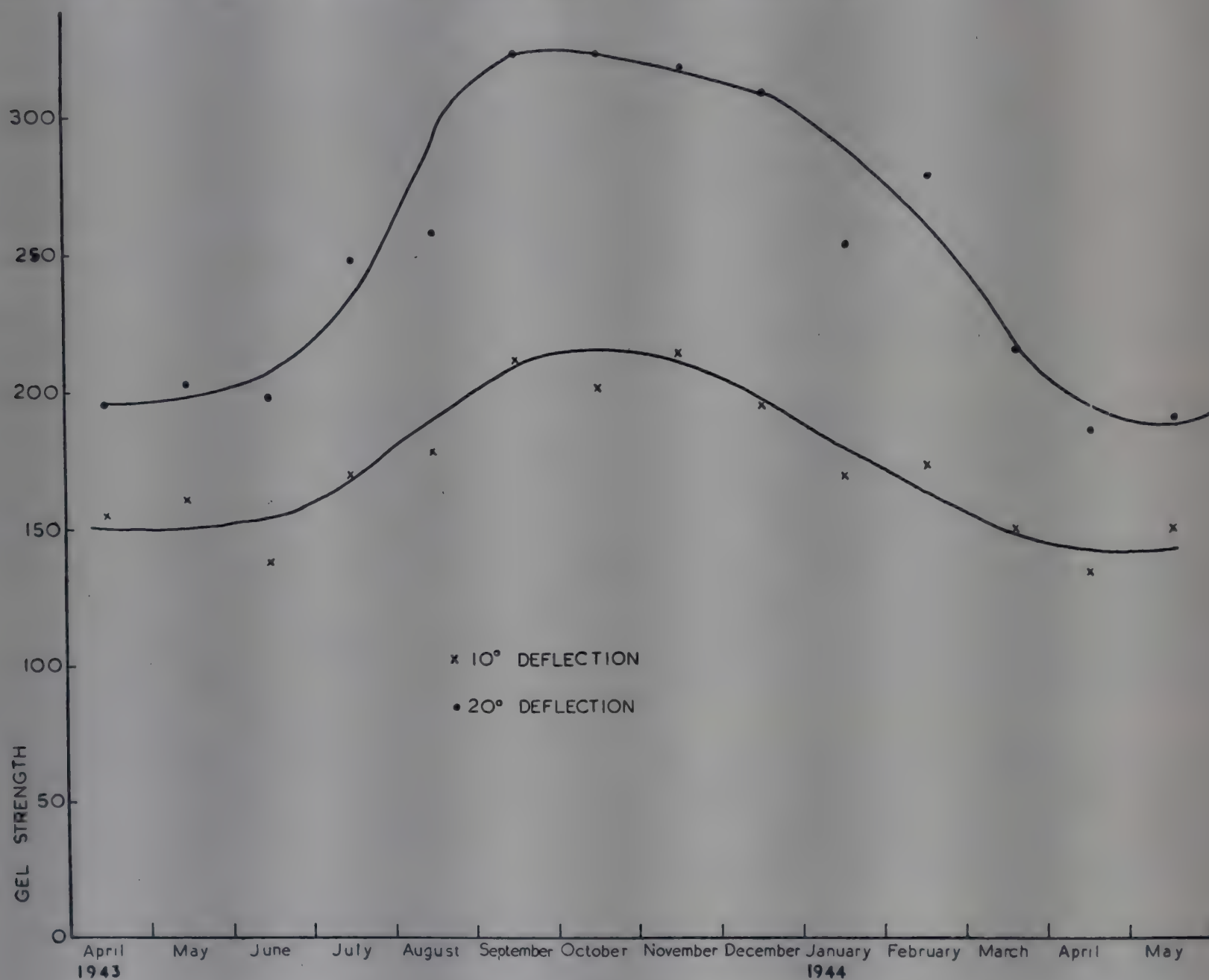
EFFECT OF TEMPERATURE ON DRYING AGAR

12 HRS. AT °C.	MOISTURE %	MELTING POINT °C.					SETTING POINT °C.					HELD SLOPE IN %	HARD ENOUGH IN %	JELLY TEST	
		1%	2%	2½%	3%	4%	1%	2%	2½%	3%	4%			10°	20°
c. 60°	10.03	44	55	58	60	64	25	35	37	40	45	2	2	237	353
70°	4.24	43	56	60	61	65	26	35	38	40	44	2	2	241	360
80°	0.65	42	54	57	60	64	25	35	37	40	44	2½	2	228	348
90°	0.72	45	55	58	61	66	26	35	38	40	44	2½	2	229	347
100°	0	42	53	57	59	63	26	34	38	40	44	2	2	216	331
110°	0	41	53	57	59	63	25	35	38	40	45	2	2	196	298

variation. Although the viscosity changed from sample to sample the changes showed no relation to season and were probably caused by slight variations in technique.

The gel strength improved from April onwards, reaching a maximum from September to December. After this there was a gradual fall to the values found in spring. These results suggest that the *Gigartina* should, from the point of view of gel quality, be collected from July to December. As is shown in the botanical section of this paper (see p. 29 *et seq.*), the weed grows

whom we are indebted for the samples (see p. 48 *et seq.*). The control areas had not been picked throughout the year. Some plots had been harvested three times (in spring, summer and autumn), and others every month. In addition one had been scraped completely bare nineteen months previously. Although there was some variation in the quality of the gels produced, it bore no relation to the intensity of harvesting. Some of the strongest gels came from plots which had been harvested monthly and one of the weakest was from a rich control area.



TEXT-FIG. 42

Seasonal variation in the gel strength of agar from Gigartina

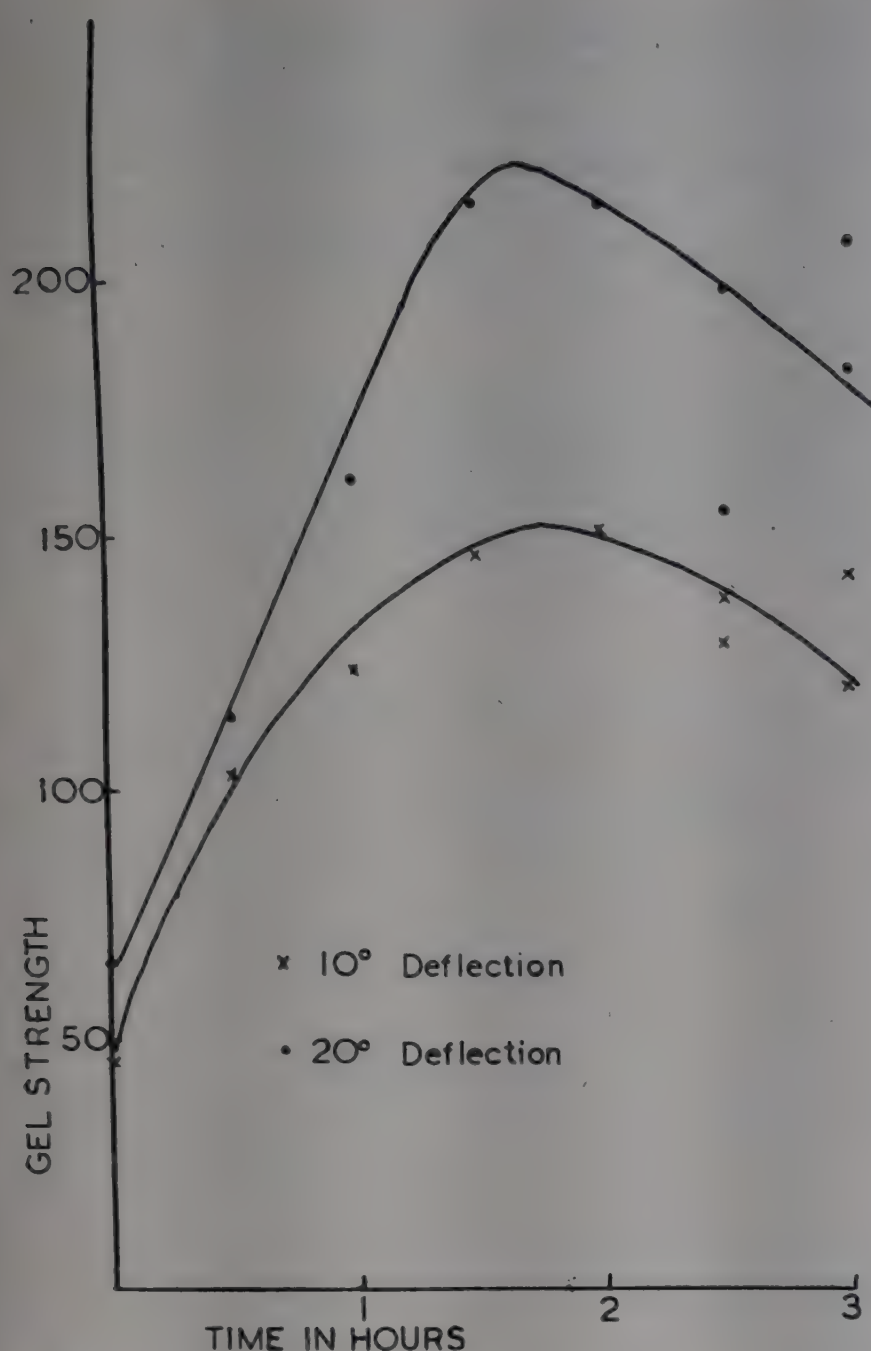
very rapidly in spring and early summer, and harvesting then would be uneconomical; if harvesting is delayed for a month or two a given area of rock carries a much greater crop. In addition the period of spore discharge and the prevalence of autumnal rough seas make it undesirable to harvest later than September.

To find the effect of different intensities of harvesting on the quality of the agar, samples were taken in October from plots in two separate areas, one extremely rich and the other only moderately rich. These plots had been harvested in different ways by E. Conway to

THE AGAR FROM *CHONDRUS CRISPUS* (L.) STACKH.

Although *Gigartina stellata* was used for the chemical work because it was abundant in the immediate neighbourhood of the laboratory, surveys in other parts of Britain showed that in some areas, as for example in Devon and Cornwall, a harvest of both *Gigartina* and *Chondrus* was obtainable. It was therefore essential to find out whether an agar could be made in the same way from *Chondrus* and what would be the effect of a mixture of the two weeds.

Carrageen, as sold, is a mixture of both, although



TEXT-FIG. 43

Effect on gel strength of autoclaving at 40 lbs./sq. in. (Chondrus)

Chondrus usually predominates and commercial samples were examined to find out the proportions of the two weeds. In their young stages, before the fruiting bodies develop, the two species are very difficult to distinguish. In a sample of Irish carrageen there was, by weight, 84% Chondrus, 8% Gigartina and 8% waste.

Samples of pure Chondrus or commercial carrageen treated in the same way as Gigartina, i.e. washed, extracted with lime, and the extract treated with potassium hydroxide, gave a very similar agar. The setting points are much the same, but the range between melting and setting points is somewhat greater. The viscosity of the first extract was greater than in Gigartina (see Text-fig. 36); that of the final agar was much the same. The gel strength was of the same order.

Like Gigartina, Chondrus improved with storage and a preliminary washing of the weed resulted in improved gel strength. The rate of loss of weight on washing Chondrus is different from that on washing Gigartina (see Text-fig. 35 and Table 21) in that the rapid loss continues for one to two hours instead of only fifteen minutes and the weed goes on losing weight slowly up to at least 24 hours. The changes in viscosity with washing and the effect of salts are similar to those in Gigartina (Text-fig. 36).

To find the effect of pressure treatment with potassium hydroxide on the quality of the agar a series of experiments was carried out by D. Byrne whom we wish to thank for permission to use the results. These were done on commercial carrageen of Irish origin containing 87% Chondrus and 4% Gigartina. The results are shown in Text-fig. 43 and Table 24 (p. 93), and indicate that the most suitable treatment is, as with Gigartina, for 1½ to 2 hours at 40 lbs. per sq. in.

No other differences apart from those described above were found between the agars from Chondrus and Gigartina.

Collections of Chondrus were made at approximately monthly intervals at Aberayron (Cards.) from 1943 onwards and at Falmouth from 1945 onwards. These were treated in the usual way. The results were somewhat irregular but showed variations which may perhaps be related either to the physiological condition of the plant, or to the fact that Chondrus has two maximum sporing periods, a tetrasporic peak in winter and a carposporic peak in summer. Butler (1936) has already shown that there is a seasonal variation in the carbohydrate content, the maximum being reached from June

TABLE 17

EFFECT OF STORING ON QUALITY OF AGAR

WEED	DATE COLLECTED	DATE EXTRACTED	YIELD IN 1ST AND 2ND EXTRACTIONS	HELD SLOPE IN %	HARD ENOUGH IN %	JELLY TEST IN 2%	
						10°	20°
New growth	April	April 6th	c. 26%	3	2½	57	89
New growth	April	April 7th	28%	3	—	71	117
New growth turned pink	April	April 29th	32%	2½	2	92	155
Old growth	April	April 15th	30%	3	—	82	137
Old growth turned pink	April	May 6th	35%	3	2½	120	216
Old growth stored	April	Dec. 12th	45%	2½	3	155	196
Old growth	Sept.	Sept. 16th	37%	3	2	166	278
Old growth stored	Sept.	Jan. 26th	51%	2	2	211	323

to September (up to 70%) and the minimum from January to March (just over 30%). Further work is in progress.

Two extractions were made from the deep-water form (var. *filiformis*) one sample having been collected in March and one in October. In both cases the gel was weak and the yield low. Further observations on the fruiting periods of this variety are in progress.

PROPERTIES OF GIGARTINA AGAR IN COMPARISON WITH OTHER AGARS

PHYSICAL AND CHEMICAL PROPERTIES

During the course of the work a number of agars from different sources was received for examination. As a standard of comparison an American product, Difco Bacto agar, was used since this is one of the best available bacteriological agars of the Japanese type.

Japanese agar imbibes water slowly and when used in strip form must be allowed to soak for several hours

TABLE 18
COMPARISON OF THE VISCOSITIES OF DIFCO AND GIGARTINA AGAR

AGAR	MOISTURE %	STRENGTH	VISCO-METER NO.	VISCOSITY IN CENTISTOKES							
				50° C	48° C	46° C	44° C	42° C	40° C	38° C	36° C
Difco	17.9	1%	2	3.26	3.39	3.54	3.71	3.87	4.05	4.30 to 4.46	—
"	"	2%	2	10.74	11.27	11.77	12.41	13.07	14.05	18.13 to 20.66	—
"	"	3%	3	29.8	31.7	33.4	35.4	38.9	45.0 to 52.0	—	—
Gigartina	6.2	1%	2	9.12	9.47	9.92	10.51	11.14	12.16	13.14	14.45
"	"	2%	3	33.3	36.8	41.8	49.1	57.3	68.1	84.3 to 96.3	—
"	"	3%	4	118	141	170	232 to 336	—	—	—	—

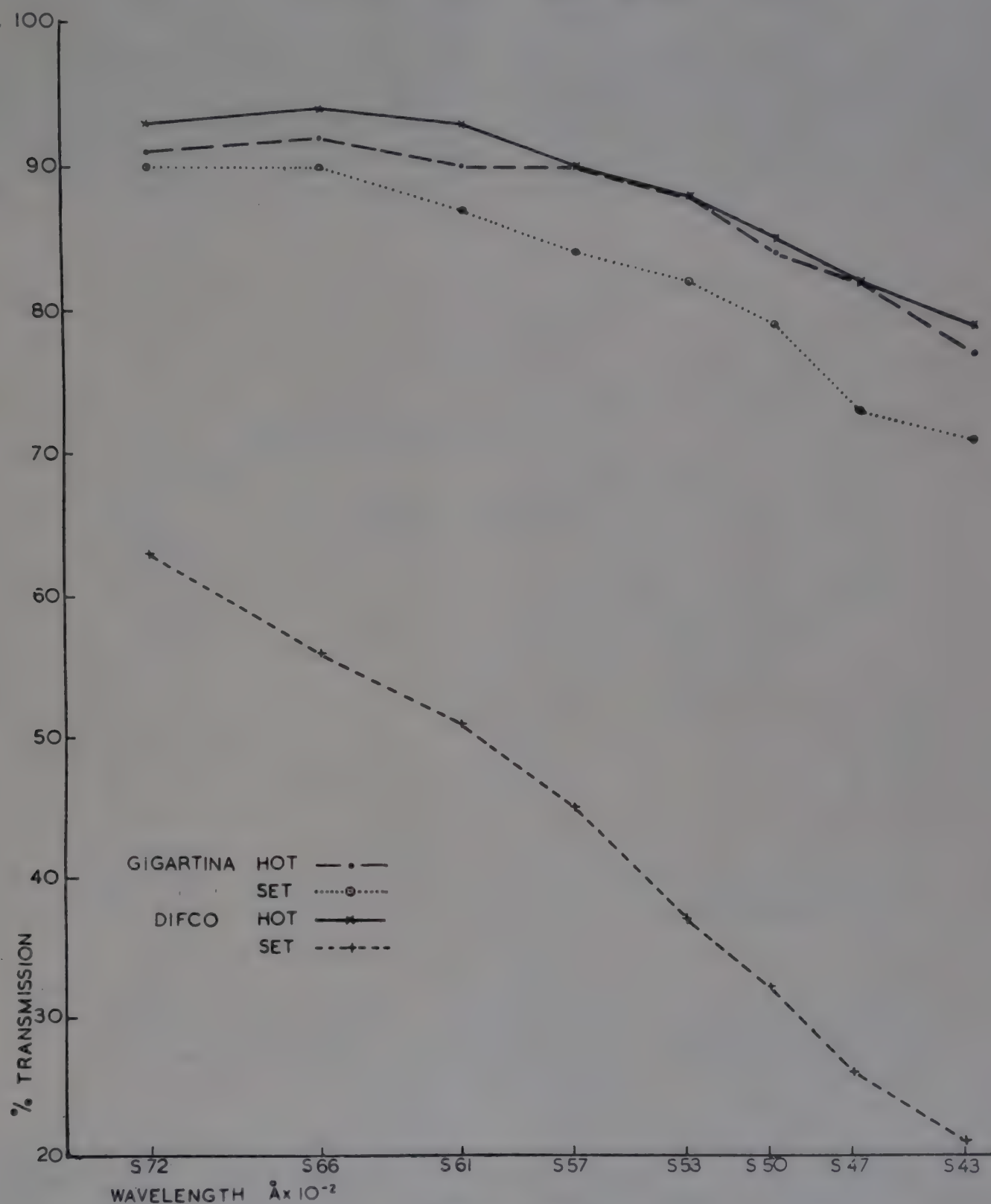
TABLE 19
EFFECT OF REPEATED STERILIZATION ON DIFCO AND GIGARTINA AGAR

NO. OF TIMES HEATED 15 MINS. AT 25 LBS./SQ. IN.				2% JELLY TEST					
				GIGARTINA AGAR		pH	DIFCO		pH
				10°	20°	GIGARTINA AGAR	10°	20°	DIFCO
I. Untreated	....	....	....	141	241	—	115	190	—
1	....	....	....	148 } 139 }	239 } 210 }	7.1	120 } 120 }	189 } 198 }	—
2	....	....	....	135	176	7.1	137	181	—
3	....	....	....	133	158	6.9	110	172	—
4	....	....	....	107	141	6.8	54	56	5.3
5	....	....	....	109	134	6.8	25	27	4.6
6	....	....	....	104	126	6.6	10	13	4.6
Heated 1 hr. at 40 lbs.	....	....	....	65	88		Did not gel		
Difco heated 2 hrs. at 40 lbs.	....	....	....						
II. Untreated	....	....	....	145	244	—	108	173	—
1	....	....	....	140	230	7.2—8.0 } NaOH added }	116	191	6.3—7.6 } NaOH added }
2	....	....	....	128	197	7.8—7.8	118	187	6.3—7.6 } NaOH added }
3	....	....	....	146	201	7.2—7.8 } NaOH added }	137	215	6.2—7.9 } NaOH added }
4	....	....	....	158	205	7.2—8.0 } NaOH added }	147	214	6.4—8.3 } NaOH added }
5	....	....	....	150	216	7.6—7.6	147	240	6.2—8.2 } NaOH added }
Concentration at end : Gigartina agar 2.4%, Difco 2.54%	....	....	....			7.2			6.3

before dispersing. Even when ground it dissolves much more slowly than Gigartina agar which when moistened with water imbibes it immediately to form a thick paste and continues to do so with further dilution. Solution of Japanese agar takes place between 90° and 100° C. whereas Gigartina agar is completely dissolved at about 70° C.

on setting is comparatively slight. The results of a comparison of the two in the Pulfrich photometer are shown in Text-fig. 44. In Difco agar the change in transparency takes place gradually and it continues to get more opalescent for some hours after setting.

Both Difco and Gigartina agar show syneresis to a small extent.



TEXT-FIG. 44

Percentage transmission of light by Difco and Gigartina agar before and after setting, compared with distilled water

(Based on data contained in Table F in the Ministry of Supply Permanent Record Monograph No. 11,145)

When melted, both Difco and Gigartina agar solutions are transparent and have a faint straw colour. There is little difference in appearance between them, although inferior Japanese agars are cloudy. When set, Difco and other agars of Japanese type become opalescent, whereas in Gigartina agar the change in transparency

The first extract from Gigartina is a very viscous fluid (see p. 73), but the potassium hydroxide treatment decreased the viscosity considerably, which is an advantage in manipulation. A comparison of Gigartina and Difco agar in 1%, 2% and 3% solution is shown in Table 18. Gigartina agar is decidedly more viscous

and the viscosity increases more rapidly at low temperatures.

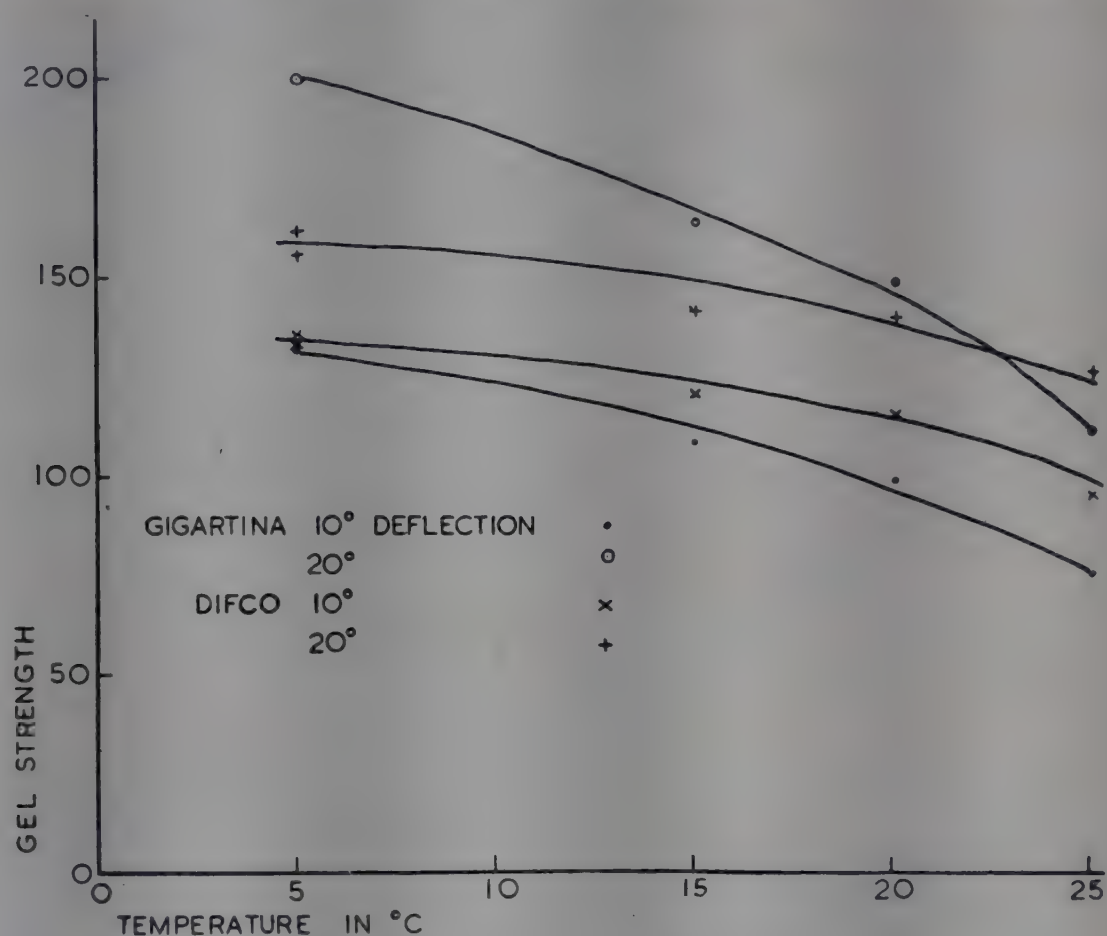
In contrast to Difco agar where the melting and setting points are practically independent of concentration, those of Gigartina agar are closely dependent on it. In contrast to those of Gigartina agar, the melting and setting points of Japanese agar are not affected by the presence of solutes in low concentrations (see Text-figs. 30-33).

Variations in the pH value of Gigartina agar made up in solutions ranging from pH 2.6 to pH 8.5 have no effect on melting point, setting point or slope-holding capacity. If however the acid solutions are heated for some time hydrolysis takes place. At pH 2.2 even

(over 30° C.) Gigartina agar is much weaker than Difco agar but at low temperatures (less than 5° C.) it is stronger.

With increasing concentration of the gel, the gel strength naturally increases, but that of Gigartina agar increases more rapidly than that of Difco so that whereas up to about 2% a Difco gel is stronger than a Gigartina, above that strength a Gigartina gel is stronger than a Difco (see Text-fig. 46).

An agar gel if heated under pressure repeatedly, tends to break down. An experiment was made to test the rate of hydrolysis of Gigartina and Difco agar under the conditions necessary for sterilization. A 2% solution of each was made up and they were subjected to six



TEXT-FIG. 45

Comparison of the gel strengths of Gigartina and Difco agar at different temperatures

(Based on data contained in Table G in the Ministry of Supply Permanent Record Monograph No. 11,145)

without heating the melting and setting points are lowered and the slope-holding capacity decreased.

The ash content of Gigartina agar is high (20-30%), partly because of the high ash content of the original extract (15-23%; see Butler, 1936), and partly because of the potassium chloride necessary for hardening the gel. Good Japanese agars on the other hand have a very low ash content (4% or under); those with higher values contain impurities.

The gel strength of Gigartina agar is much more dependent on the temperature at which it is measured than is Japanese. In Text-fig. 45 the relative strengths of 2% solutions of Gigartina agar and Difco agar at different temperatures are given. At high temperatures

15 minute periods of heating in an autoclave at 25 lbs./sq. in. The gel strength was measured between each period. The results show (Table 19, I) that Gigartina agar is more resistant to this treatment than Difco agar and that this is because the pH value of the Difco solution falls much more rapidly. A further experiment (Table 19, II) showed that if, between successive sterilizations, the pH was brought back to pH 7 or 8 there was practically no alteration in gel strength and indeed it increased a little owing to the evaporation which occurred on heating. Sterilizing at 40 lbs./sq. in. for an hour however destroyed the gel.

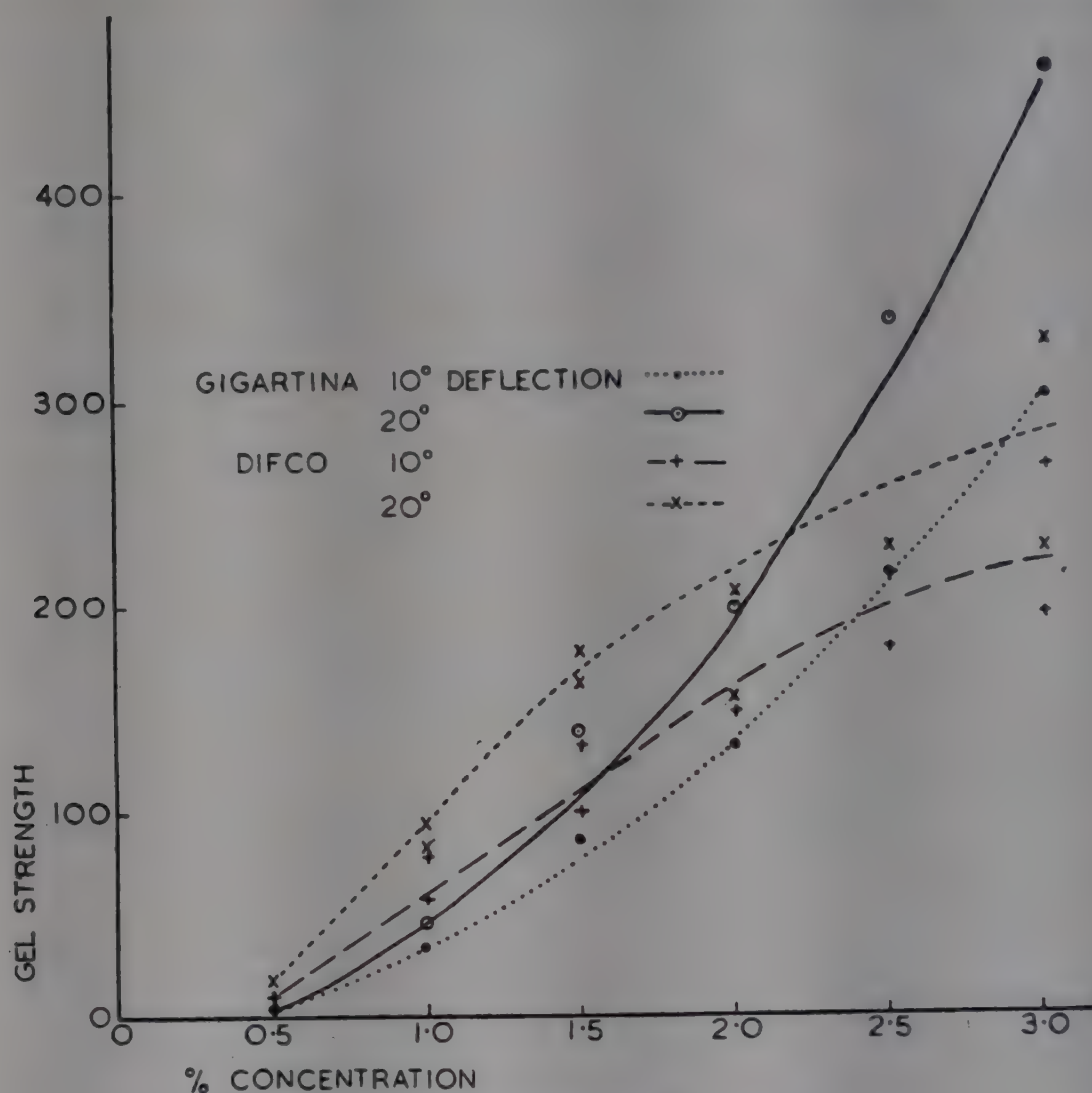
Since Gigartina and Difco agars each have some advantages it was thought that mixtures of the two might

be suitable for bacteriological work. Mixtures in varying proportions were tested, but were not found suitable.

The effect of a number of different salts on gel strength was tested. The agar used was a pressure-treated *Gigartina* agar produced commercially and used in 2% solution. Some thirty salts in 1% solution were tried, mainly the common compounds of sodium, potassium, ammonium, magnesium and calcium. Of these the majority had no appreciable effect on gel strength although, with the exception of sodium salts, they raised the melting and setting points considerably. The salts which raised the gel strength appreciably were potassium

setting points were 40° C. and below, the gel strength was high and the solution became opalescent on setting. The melted agar however was not quite clear. Another very small sample from Ireland appeared to be of the same type but it was very viscous and did not go completely into solution.

A South African agar made from *Gracilaria confervoides* had similar melting and setting points to those of *Gelidium* agar but did not dissolve completely. The gel strength was considerably lower. The solution was not viscous; even after filtering it was much less transparent than Difco agar both melted and as a gel. The



TEXT-FIG. 46

Comparison of the gel strengths of *Gigartina* and Difco agar in different concentrations

(Based on data contained in Table H in the Ministry of Supply Permanent Record Monograph No. 11,145)

chloride, potassium sulphate and potassium hydrogen phthalate. As mentioned earlier, potassium iodide made the gel elastic and the gel strength as measured by the Jelly Tester was very low. These tests would have been more satisfactory if made on a dialysed agar but the preparation of large quantities of this is difficult in the laboratory.

AGAR FROM OTHER SOURCES (Table 20)

A small sample from Portugal had the characteristics of a *Gelidium* agar, i.e. melting points were over 90° C.,

solutions especially when dilute showed very marked syneresis.

All the above specimens appeared to have been purified to some extent by freezing and thawing. A sample from India however, made from *Gracilaria lichenoides*, was in tough yellow strips and seemed to have been sun-dried without this treatment; it did not dissolve completely. The melting point was about 90° C. but the setting points varied from about 42° C. in 1% solution to 50° C. in 3% solution, which is rather high for bacteriological work. The gel strength was slightly below that of the S. African agar. An attempt

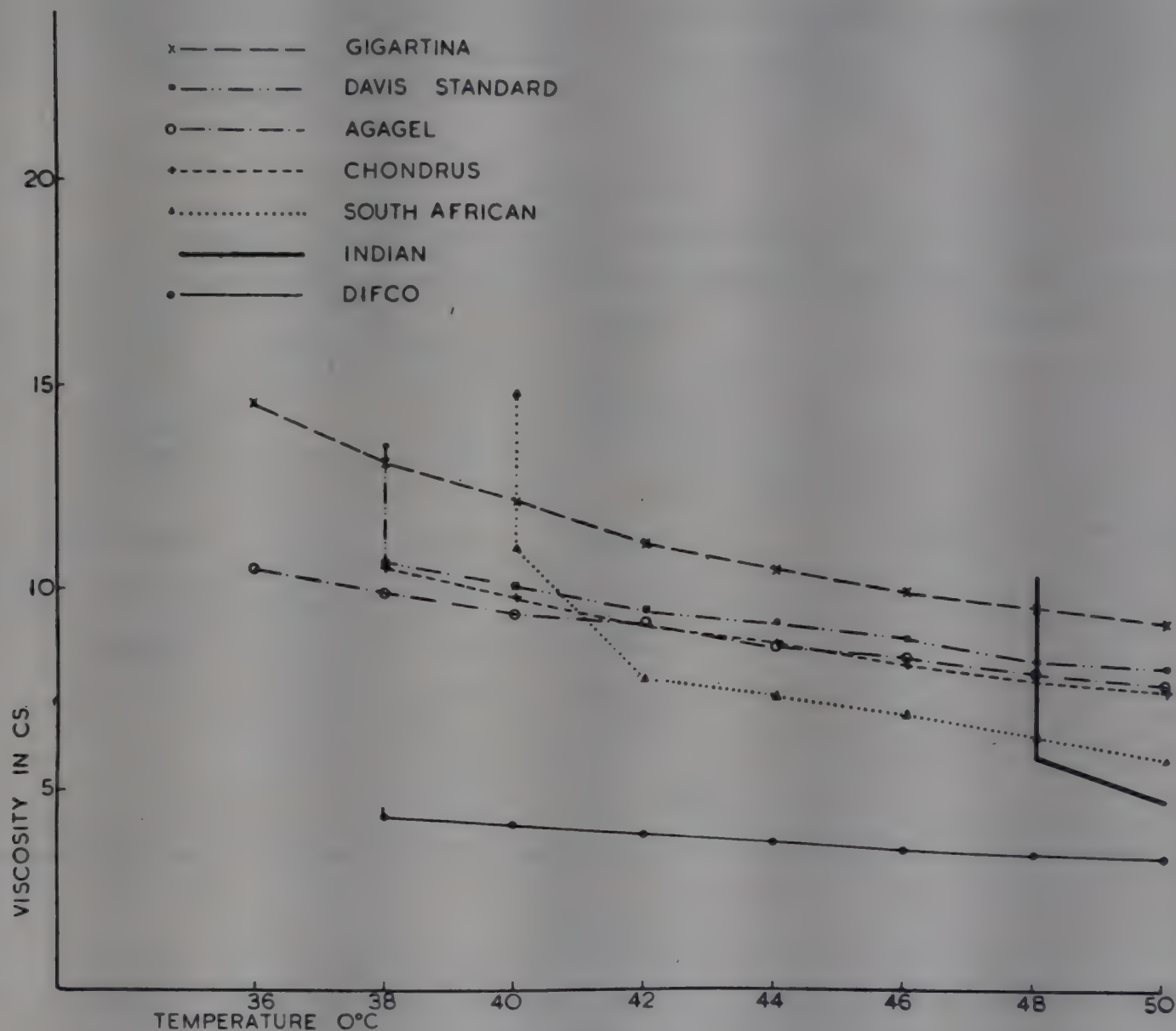
was made to improve it by dissolving it, cutting the gel in strips, freezing and allowing to thaw. The gel produced from this purified agar was however a good deal weaker than before. It therefore appears that *G. lichenoides* is not such a suitable species as *G. confervoides* for agar production.

A sample of agar made in New Zealand from *Pterocladia lucida* dissolved with difficulty to give viscous solutions. The melting point was very high (about 100° C.) and even a 1% solution held a slope at blood temperature and had a firm surface. A later

The change of viscosity with temperature of these agars is shown in Text-fig. 47.

Difco agar maintains a low viscosity almost to its setting point. Of the other agars tested, the viscosity of South African and Indian approached that of Difco but their setting points were high.

Considerable stocks of *Eucheuma muricatum* from the Far East were available in this country. Species of *Eucheuma* are said to produce an agar and several experiments were made to find the best way of doing so. Boiling it up with water alone produced only a weak and



TEXT-FIG. 47

Comparison of the viscosities of agars from different sources (1% solution in distilled water).
(Based on data contained in Table I in the Ministry of Supply Permanent Record Monograph No. 11,145)

sample (Davis Standard Agar) was greatly improved; it dissolved completely, was much less viscous and had a high gel strength.

A Chondrus product called Agagel was received from the U.S.A. It resembled Gigartina agar in several respects, viz. the melting point was low, and melting and setting points varied considerably with the concentration. The gel strength however was low and a high concentration (4%) was needed to give a firm surface.

syrupey gel with a low melting and a high setting point. An extract made with lime held a slope at 37.5° C. in 5% solution but the setting points were all much too high for bacteriological agar and there was a gap of only about 2° C. between melting and setting points. Electrolytes had some effect but raised both melting and setting points and even in 1% potassium chloride this extract held a slope only in 5% concentration and this had too soft a surface for bacteriological work.

The treatment with potassium hydroxide, found successful with *Gigartina*, was also tried both on unwashed and washed *Eucheuma* and with and without pressure. There was a slight improvement (see Table 20) though pressure treatment was too violent. The washed weed treated with potassium hydroxide without pressure gave a product which held a slope in 3% solution but in all there was only a small gap between melting and setting points. None of the products was suitable for bacteriological work.

TESTS WITH BACTERIOLOGICAL MEDIA

During the experimental work on *Gigartina*, samples of the different products were sent for testing to various bacteriologists and as a result of their criticisms modifica-

tions were made in the methods used. The agar eventually produced was reported on favourably by the bacteriologists but a number of differences from Difco agar were noted and some slight modifications of bacteriological technique were necessary. A report by the bacteriologists is given as Appendix I.

A manufacturing process based on this chemical work forms the subject matter of patent protection both in Britain and abroad.

The data for Text-figs. 30-34, 36, 37, and 44-47 have been omitted to save space, but they are contained in the Ministry of Supply Permanent Record Monograph, No. 11,145, copies of which are held in the Directorate of Chemical Research and Development, Shell Mex House, London.

TABLE 21
LOSS OF WEIGHT ON WASHING GIGARTINA AND CHONDRUS

TREATMENT	TIME OF WASHING	% LOSS		TIME OF WASHING	ASH CONTENT OF GIGARTINA %
		GIGARTINA	CHONDRUS		
Dried weed not rinsed	5 minutes	12.0		Unwashed	18.12
	3 hours	20.9		10 minutes	11.90
	6 "	23.7		1 hour	11.80
	12 "	20.1		3 hours	11.46
Freshly collected and rinsed while alive	5 minutes	15.6	15.0 14.1	6 hrs. 10 mins.	12.48
	15 "	20.1	10.9 15.6	20 hours	12.42
	1 hour	20.2	22.4 21.4	43 hours	13.29
	2 hours	21.6	22.3 23.2		
	6 "	22.0	24.5 25.1		
	24 "	20.6	30.9		
	48 "	21.9			

TABLE 22
PERCENTAGE TRANSMISSION OF LIGHT THROUGH AGAR (DECOLORIZED WITH DIFFERENT AMOUNTS OF CHARCOAL) AGAINST DISTILLED WATER

% ACTIBON	TREATMENT	COLOUR	SPECTRUM FILTERS ($\text{\AA} \times 10^{-3}$)							
			S72	S66	S61	S57	S53	S50	S47	S43
0	Untreated	Yellow, clear	92.5	88.8	80.1	72.8	65.2	54.0	45.1	32.0
0	2½ hrs. heating on water bath .....	.....	91.1	87.9	79.1	73.6	63.3	53.2	43.0	31.4
0.05	Shaken not boiled	Pale yellow	81.7	80.0	75.2	70.5	65.4	57.1	49.3	40.0
"	Boiled 5 mins.	"	87.1	85.9	82.1	76.1	70.7	61.8	55.8	45.7
"	10 "	"	78.5	74.9	72.2	69.4	64.0	57.5	51.3	43.6
"	15 "	"	88.3	86.4	83.6	78.1	72.5	62.7	56.9	46.0
"	30 "	"	83.3	81.3	77.7	74.1	67.8	61.1	55.2	44.1
0.15	Shaken not boiled	Yellow	79.0	78.0	76.8	73.3	68.8	63.2	55.9	47.8
"	Boiled 5 mins.	Colourless	85.3	85.5	82.2	78.9	78.1	75.4	74.9	69.6
"	10 "	"	84.2	85.3	84.4	81.5	79.3	76.4	74.4	71.0
"	15 "	"	89.5	88.3	85.7	83.9	82.3	80.8	77.5	74.5
"	30 "	"	88.9	88.9	85.6	84.0	83.0	78.4	73.9	67.0
0.30	Boiled 5 mins.	"	80.4	80.1	79.5	76.7	76.4	75.0	73.4	74.3
"	15 "	"	85.0	86.0	85.3	83.8	81.7	80.5	78.6	76.2

TABLE 23

SEASONAL VARIATION IN THE GEL STRENGTH OF GIGARTINA STELLATA

DATE COLLECTED	DATE EXTRACTED	JELLY TEST IN 2%		Cl %	% EXTRACTED IN TWO EXTRACTIONS	VISCOSITY OF 1% SOLN. AT 40°C. IN C.S.
		10°	20°			
1943						
April	17.12.43	155	196	3.9	44.7	—
May	16.12.43	161	203	4.5	46.8	16.6
June	15.12.43	139	198	4.9	46.0	15.7
July	13. 1.44	170	248	4.2	52.0	11.9
August	19. 1.44	178	259	4.5	47.7	11.0
September	26. 1.44	211	323	4.8	50.8	11.9
October	27. 1.44	202	324	5.1	51.6	15.8
November	1. 2.44	214	318	5.3	43.0	14.8
December	2. 2.44	196	309	4.9	41.9	20.3
1944						
January	17. 5.44	170	254	5.1	43.7	13.5
February	18. 5.44	174	279	5.9	42.5	16.2
March	29. 6.44	151	217	6.4	45.6	11.0
April	25. 7.44	135	187	5.3	49.2	9.5
May	16. 8.44	151	191	4.4	47.2	13.8

TABLE 24

EFFECT OF PRESSURE ON POTASSIUM HYDROXIDE TREATMENT OF CHONDRUS

PERIOD OF PRESSURE AT 40 LBS./SQ. IN.		MELTING POINT °C.					SETTING POINT °C.					HARD ENOUGH IN %	HELD SLOPE AT 38°C. %	GEL TEST IN 2% SOLUTION	
		1%	2%	2½%	3%	4%	1%	2%	2½%	3%	4%			10°	20°
No Pressure		47	56	61	65	70	25	32	37	44	59	2½	2½	46	65
½ hour		54	62	64	68	74	29	37	40	44	54	2	2½	103	114
1 hour		52	59	64	68	72	35	38	40	43	52	2	2½	124	162
1½ hours		51	60	64	66	72	38	39	40	41	49	3	2½	147	216
2 hours		50	59	63	66	73	28	35	37	42	46	2½	2½	152	216
2½ hours	1.	47	51	60	64	68	26	33	35	36	41	2½	2½	129	156
	2.	47	52	61	64	69	25	33	35	36	41	2½	2½	138	199
3 hours	1.	48	62	64	66	71	29	38	39	41	53	2½	2	143	209
	2.	49	61	63	65	70	29	37	39	40	53	2½	2	121	184

SUMMARY AND CONCLUSIONS

AGAR, an extract from certain seaweeds, dissolves in water and sets to a firm jelly. Before 1939 it was made chiefly in Japan from various algae, though the United States of America produced a small quantity. Agar was used for a great variety of medicinal, scientific and commercial purposes, but after the outbreak of the second world war its use in Britain and the U.S.A. was restricted by law. Agar is unrivalled as a medium for the growth of certain bacteria, having great advantages over animal gels. On account of its use in the preparation of protective injections for the armed forces, all belligerent countries needed a supply of the product. With the entry of Japan into the war the position became even more acute and attempts at agar manufacture from weed available locally are known to have been made in the U.S.A., New Zealand, Australia, South Africa, India, Ceylon, Eire, Russia, China, Portugal, Italy and Great Britain. As far as has been ascertained, no agar was made in France; Germany appears to have relied on earlier stocks and on the recovery of previously used material.

The degree of urgency, the availability of material and other factors, have dictated the extent to which the investigation of the autecology of the various seaweeds used in different countries has been studied. Although to a large extent common problems have had to be faced, the facility with which the available weeds could be harvested has been the main controlling factor in the pursuance of such investigations.

In Britain, though a stock of agar had been stored by the Government, it was deemed necessary to seek a local source of further supplies. Although a good agar could have been made by simple extraction from *Gelidium corneum* Lamour. *Ahnfeltia plicata* Fries or *Gracilaria* sp., none of these seaweeds was present in sufficient quantity for large-scale collection. Preliminary chemical and botanical investigations led to the conclusion that the red seaweeds *Gigartina stellata* Batt. and *Chondrus crispus* (L.) Stackh. could be used as a source of agar, having regard to both the availability of the raw material and the suitability of the resulting product. Accordingly, surveys of coastal areas of Britain were undertaken in order to ascertain where these plants occurred in sufficient quantity to justify a harvest, and investigations also began on the life-history of *Gigartina* and the autecology of both *Gigartina* and *Chondrus*. In addition, experiments were undertaken to find the best methods and times of harvesting, taking into consideration the modes of growth and fructification, the maturation and regeneration of the plants and the seasonal fluctuations in the gel strength of the extract. When it was found that not more than 5% of the total harvest would be *Chondrus* and that this proportion

did not affect the process of manufacture, experimental work was confined largely to *Gigartina* though some work on the seasonal fluctuation of the gel strength in *Chondrus* is still in progress.

Inevitably the investigation is as yet incomplete, but enough has been ascertained to enable annual harvests to be taken and a satisfactory bacteriological agar to be manufactured.

SURVEYS

Coastal areas likely to yield harvests were visited and were reported upon or surveyed in detail, dependent upon their richness. Harvestable areas were confined to the west coast of Britain and the coast of Northumberland. The richest localities were on the islands of the Clyde sea-area, though high yields were also reported on the Islands of Skye, Mull and Tiree, off the west of Scotland, as well as on the coasts of Anglesey, other parts of Wales, Devon and Cornwall.

BOTANICAL WORK

Gigartina stellata Batt.

About 95% of the total red weed harvested proved to be *Gigartina stellata*, the rich harvestable districts of the Clyde sea-area yielding no *Chondrus crispus* at all. From examination of a large number of specimens from many localities it would appear that the type species of *Gigartina stellata* Batt. merges under certain conditions into var. *prolifera* Turn., and that var. *incurvatus* Turn. is a growth form of var. *acuta* Good. & Woodw., which bears linear papillae on which spermatangia are borne. It seems correct therefore to regard the species *Gigartina stellata* Batt. as consisting of the type and the var. *acuta* Good. & Woodw. Var. *prolifera* Turn. and var. *incurvatus* Turn. are not regarded here therefore as true varieties, but as growth forms of the type species and of var. *acuta* Good. & Woodw., respectively. The anatomy of the type species has been found to conform to earlier descriptions.

New growth accelerates in spring and by May deep pink new thalli can be observed in abundance. There is some indication that seasonal temperature fluctuations cause a variation in the time at which such growth begins. The new pink thalli, which may arise either from one of the layers of the basal holdfast or from behind a damaged portion of an old thallus, often pass through an olive-green phase particularly in the more southerly localities and then become dark-red and horny. The papillae which ultimately bear cystocarps can be seen first as small spots on the young thalli and later as protuberances from the surface of the thallus when the latter becomes cartilaginous. As the thallus matures,

the cortical cell rows as seen in transverse section increase in number along one radius, from 4-5 in April, to 10 in September and the cell walls increase in thickness. The secondary pore connections in the inner cortical layer and medulla also become more numerous. The increase in the width of the cortex and the thickness of the walls shows a correlation with the increase in gel strength which is of major importance in agar manufacture. The age of individual plants can be calculated from the layering of the holdfast and new thalli may arise from the surface layer of the holdfast or from its deeper older layers. Examination of holdfasts and of marked plants indicates that in some districts *Gigartina* behaves as an annual, though in most others the plants are pseudo-perennial and regenerate from the holdfast for several successive years. In autumn many of the old heavy fronds are torn away above the holdfast and investigations are in progress concerning the parts played by browsing animals and by possible variations in the tensile strength of the plants at that time. The fact that regeneration takes place freely from the holdfast is of major importance in harvesting.

The life-cycle of the plant is as yet incompletely understood and work on the cytology is still in progress. Spermatangia have been seen on the thalli or on linear papillae, and carpogonial branches are also developed in papillae arising from the thallus. A spermatium has been seen attached to a trichogyne. Presumably fertilisation takes place, though this has never actually been observed, and carpospores are borne which have been seen to be discharged through a lateral ostiole. The cystocarps reach a peak of maturity in July and August when the cortical cells are at a maximum and their cell walls thickest. The maximum period of spore discharge appears to be from September to December. No tetrasporic plants have ever been identified. At first, the most urgent problem was concerned with seasonal regeneration and no attempt was made to elucidate the obscure life-history of the plant. Later, preliminary attempts were made to grow the spores in culture and on the shore, and to examine the cytology of the plant in order to ascertain the position of reduction division in the life-cycle. These investigations are still in progress though the attempts to grow spores on cleared areas on the shore have shown that there is usually a recolonisation sequence of diatoms and green algae, often followed by some members of the Phaeophyceae and/or Rhodophyceae before *Gigartina* re-establishes itself. The effect of clearing areas at different times of the year has also been investigated. As the spores appear to be unable to colonise bare rock surfaces directly, there would be practical difficulties in the culture of *Gigartina* on prepared bare substrata put into the sea, as has been done commercially elsewhere by the Japanese and others for *Porphyra* and *Gracilaria*.

The study of the ecology of *Gigartina* has shown that the plant occurs usually in well-aerated water, free

from mud, on exposed or semi-exposed coasts, near low water of spring tides, at the base of the *Fucus serratus* zone, either in discontinuous tufts on boulders or forming an almost continuous belt sometimes as wide as 20 yards. When growing under optimum conditions it is frequently associated with *Himanthalia lorea*. Other communities of which *Gigartina* is a component are also described, and some evidence is cited of the tolerance of *Gigartina* for water of relatively low salinity and high bacterial count, the latter indicating sewage pollution. At the limits of its up-shore range, small plants of *Gigartina* may be found growing beneath the overlapping thalli of *Fucus serratus*, but removal of these brown algae causes the plants to deteriorate, probably because desiccation is too great at that level in the littoral zone when the protecting *Fucus* thalli are removed.

There appears to be no general correlation between geological formation and the occurrence of *Gigartina* except in so far as the nature of the strata influences the configuration and topography of the shore in the lower littoral zone and the structure of the rock surface determines the provision of a suitable substratum for the lodgement of the spores. The prevalence of exceptionally high winds and heavy seas appears to be a deterrent to the presence of *Gigartina* and there is some evidence that the plant can occur higher up-shore in regions where low water of spring tides is in early morning and evening and the period of maximum exposure thus never occurs during the hottest part of a summer day. This is further evidence for the suggestion that *Gigartina* cannot tolerate extreme desiccation. On the coasts of the Clyde sea-area where *Gigartina* is especially well developed it may be noted that the following favourable factors are all operative together, suitable substratum, boulders or ledges in the appropriate zone, good oxygenation yet with some shelter from the full force of the Atlantic and the time of low water of spring tides never in the hottest part of the day. Observations have been made on the marine animals associated with *Gigartina*, and on its attack by limpets, which latter has been especially apparent in the dense carpets of weed on the Cumbrae.

Experimental work on growth and regeneration has been carried out, in order to decide the time when a harvest might safely be taken without endangering future supplies and also to determine the most suitable dates and the most advantageous manner of gathering. Temporary arrangements were made in the early years but finally, having regard to the results of experimental work on the modes of growth and regeneration of the plants, it was decided that only one harvest per year should be taken, between and including the first suitable tide in July and the last available tide in September. As a result of a number of experiments in different localities on methods of harvesting, instructions were given that the material should be hand picked, not sheared, and that care should be taken not to destroy

the holdfast. These instructions took into account the season of growth and ensured that a maximum weight would be available per plant. Harvesting thus ceased at the time of maximum spore discharge and it was hoped that the presence of inaccessible plants would form a reserve of spores for new sporelings and that the preservation of the holdfast and basal parts of some thalli *in situ* would ensure regeneration after harvest. The results of weeding experiments indicated that such a practice would result in no commercial gain.

Chondrus crispus (L.) Stackh.

Preliminary investigations have been made on the ecology of *Chondrus crispus* (L.) Stackh. but these were not continued owing to the small total harvest of this weed. Confirmation was obtained of the existence of sub-littoral and littoral varieties of the plant and some observations have been made on variations in the littoral plants, which appear to be correlated with habitat. It has been ascertained that *Chondrus* is much more easily torn from the rocks than *Gigartina* and that it regenerates from the basal hapteron as well as from injured thalli. Greater care is therefore necessary in harvesting this weed than in the case of *Gigartina*. Some experimental work is still in progress on the seasonal variation in gel strength. In the case of *Gigartina*, there is definitely a close correlation between the maximum anatomical development together with the maximum gel strength of the extract, and the reproductive peak period. In the case of *Chondrus*, where there is an alternation of morphologically similar generations and where the maturation of carpospores tends to take place in summer and the formation of tetraspores in winter, it is possible that seasonal fluctuations in gel strength may be different in the two types of plant. If this proves to be the case, there may be a further difference in any bulk estimation of the gel strength of the extract, owing to the percentage of tetrasporic or sexual plants in a sample, and separate investigation of the haploid and diploid plants may be necessary.

A pyrenomycete (*Leptosphaeria Chondri* (Rostr.) Rosenvinge) has frequently been observed on *Chondrus* towards the end of summer, and it is possible that this fungus contributes to the decay of fronds at the end of the fruiting season.

HARVESTING

When, during a survey, harvestable weed was found to be present in a coastal region, contacts were made locally with a view to the subsequent organisation of a team of harvesters. In order to overcome difficulties arising from the extreme polymorphism of both *Chondrus* and *Gigartina*, a botanist took charge of each area and ensured that local collectors had adequate knowledge of the plants. Fortunately *Chondrus* and *Gigartina* could be harvested together. In England and Wales

harvesting was carried out by voluntary workers and was mainly confined to Northumberland, Anglesey, Devon and Cornwall. Any remuneration paid by the commercial manufacturing firm was usually donated to local war charities. In the Clyde sea-area where *Gigartina* grows much more luxuriantly, harvesting was organised on a commercial basis. In all cases drying was either carried out locally or the weed was despatched to a drying station, if such was available near enough to be of practical value. As a result of laboratory experiments on harvested weed, harvesters drying the weed before despatching it were instructed to wash it for a few minutes in fresh water and then to dry in a warm room or in the sun, before despatching by rail. Now that hostilities are over, harvesting is continuing only in the rich Clyde sea-area, and on a commercial basis.

CHEMICAL WORK

Gigartina stellata and *Chondrus crispus* yield about 50% of their dry weight as an extract, which forms a soft and viscous gel. This untreated extract, though itself unsuitable for bacteriological work, partly on account of its high viscosity, has other commercial applications. Its viscosity was found to be considerably reduced by the addition of certain electrolytes, of which potassium chloride proved the most suitable both from a chemical and bacteriological point of view.

A preliminary washing of the seaweed (up to 12 hours in running water) removed readily diffusible salts as well as a certain amount of organic matter with undesirable properties and the effect of this washing on the final gel was to lower its viscosity and increase its hardness.

Although the simple addition of potassium chloride was an advantage, an improved product was made by heating the extract with potassium hydroxide instead and then neutralizing with hydrochloric acid. The amount of potassium hydroxide used must be carefully controlled because although it made the final gel harder, it had the disadvantage of raising the setting point. For most bacteriological work the setting point should not exceed 40° C. It was found that the amount of potassium hydroxide used should not be greater than 15% of the dry weight of the extract used.

A still greater improvement was effected by increasing the severity of the potassium hydroxide treatment. The optimum results were obtained by carrying it out in an autoclave for 8 hours at 20 lbs. or for 2 hours at 40 lbs./sq. in. With this treatment less acid was required for neutralization, which shows that partial hydrolysis had taken place.

The treatments described resulted in the production of an agar which had a deep yellow colour that was easily removed by treating with activated charcoal. It was then allowed to gel, cut up, and dried at a moderate heat.

The agar made in this way differs from Japanese agar in the following respects :

It contains a much greater percentage of inorganic material but this is an essential part of the gel complex and is not, as it would be in Japanese agar, an impurity. When melted, the transparency of British agar and of the best Japanese agar is about the same, but when set Japanese agar is much more opaque, whereas British agar remains clear.

The British product has a lower melting point and

dissolves much more readily than the Japanese. Since the melting and setting points of *Gigartina* and *Chondrus* agar are affected by the presence of electrolytes, certain modifications of bacteriological technique are sometimes necessary when the media used contain inorganic salts. It is however suitable for all ordinary routine bacteriological work, as is evidenced by the appended report of bacteriologists. The manufacturing process is protected by patent both in Britain and abroad.

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APPENDIX I

BACTERIOLOGICAL REPORT

By Jean MacNaughtan, V. D. Allison,
and Betty Hobbs

AGAR has numerous advantages over other substances used for solidifying culture media: (1) unlike gelatin, it is not liquefied by bacteria; (2) it changes readily from sol to gel and vice versa (*cf.* silica gel); (3) it remains liquid when cooled to 42°C. but when set it remains solid at 37°C.; (4) it is nearly transparent and almost colourless.

It is desirable that the plates of media should not exude moisture after drying, otherwise there will be a tendency to confluent growth, making the identification and isolation of pure cultures difficult. The colonial characteristics of bacteria grown on media incorporating Japanese agar are so generally recognised that it is desirable that if possible any other agar should largely maintain these characteristics.

Varying concentrations of Gigartina agar from 1% to 4% were tested with Lab. Lemco and tryptic meat digest broths as nutrient bases. Observations at the different concentrations were made on melting point, setting point, ability to hold slopes and plates, firmness of setting, viscosity, transparency, colour, ease of filtration, the effect of the addition of NaCl and KCl in varying concentrations on the melting and setting points, and the growth-promoting properties. The behaviour of the agar from these points of view was compared with that of Japanese agar in the usual concentration of 2%. In addition, Gigartina agar was also tested for use in solid enrichment and selective media, such as horse blood agar, MacConkey agar, desoxycholate-citrate agar, and Hoyle's blood tellurite agar, media in daily use in medical bacteriological laboratories. The organisms used for observations of the nature and type of growth, included: *Staphylococcus aureus*, *Streptococcus pyogenes*, *Corynebacterium diphtheriae*, *Neisseria meningitidis*, *Bact. typhosum*, *Bact. paratyphosum B.*, *Bact. flexneri*, *Bact. Sonnei* and *Bact. coli*. The melting and setting points were determined mainly by the method described on p. 70.

At first, untreated extracts of Gracilaria and Gigartina were examined, and also calcium and potassium compounds of Gigartina. Many difficulties were experienced with these; for example, it was necessary to use rather high (4%) concentrations in order to obtain a sufficiently firm medium. Concentrations higher than 4% were too viscous and filtration was very slow. Occasionally heavy precipitation occurred in the medium which would have made pour-plates impracticable. Setting points tended to be too high, and the consistency of the agar even in the highest concentrations was too soft for inoculation and too moist for development of discrete colonies.

Most of these difficulties were overcome in subsequent batches prepared from Gigartina and finally an agar was obtained which, when combined with nutrient bases in concentrations of 2.5-3.0%, possessed the colour and transparency of Japanese agar, had a satisfactory viscosity when melted, filtered readily, when cooled held slopes and plates for at least 48 hours, and set with a firm surface which could be inoculated with a loop or glass rod without tearing the medium. The melting point of Gigartina agar is considerably lower than that of Japanese agar, while the setting point is higher, and these vary a few degrees Centigrade, according to the nature of the nutrient base; as has already been mentioned, the melting and setting points are raised by certain electrolytes.

With the commonly used Lab. Lemco medium, owing to the phosphates present, a precipitate is produced on neutralizing, which is heavier with Gigartina agar than with Difco. The filtered solution is unchanged in gel strength although the substances added raise both the melting and setting points by several degrees. This effect is due to the Lemco; Difco meat extract has the same effect but the rise is not enough to make an alteration of methods necessary.

A similar precipitate and rise in the melting and setting points also occurs with Douglas broth. When the

digestion of the meat broth is done with laboratory prepared trypsin, such as is used by many bacteriologists, the rise is greater than with commercial meat extracts.

Yeastrel milk agar for plate counts made with 3% Gigartina agar was easy to prepare and of a satisfactory consistency. Counts were higher on Gigartina agar than on control Japanese agar plates and the colonies appeared to be larger, but in general, spreaders were more predominant on the British agar medium and this tended to make counting difficult, or at times impossible. This was attributed to the greater capacity of the Gigartina agar for exuding moisture which encourages the growth of spreading organisms.

With Yeastrel milk medium there is no alteration in melting and setting points, but although the gel strength of the unfiltered medium is somewhat higher, that of the filtrate is lower than that of the original agar.

The higher setting point of Gigartina agar necessitated the pouring of plates at a temperature of about 50°C. When blood agar plates or slopes were prepared it was found to be essential during the process of mixing blood with agar to keep all apparatus and the ingredients of the medium warmed at a temperature of 45°C.-50°C. to prevent rapid cooling and setting of the medium in the mixing flask before plates were poured. The amount of moisture which exuded on to the surface of plates after pouring (synaeresis) necessitated a longer period of drying at 37°C.-40°C. than that required for Japanese agar, in order to obtain a dry surface suitable for inoculation of test organisms or bacteriological specimens, and to avoid confluent growths. Drying at 37°C. for from one-half to two

hours was found to be necessary according to the medium used, MacConkey agar and desoxycholate-citrate agar requiring the longest time.

With the most recent batches of Gigartina agar, growths of all the test organisms were satisfactory and compared very favourably in amount and in colonial appearance with cultures on control media prepared with Japanese agar.

The properties of these recent batches of British made agar were studied more intensively in relation to dairy and agricultural work than were the earlier batches. In most instances the results have been favourable. Difficulties encountered were similar to those already described, e.g. (1) the tendency for spreading colonies to develop in poured plates—especially noticeable with Yeastrel milk agar; (2) the tendency for agar to solidify too quickly when pouring plates which need to be poured at low temperatures, e.g. milk count plates; (3) softness of the gel, which would give rise to difficulties if used for cultures which have to be scraped off, as in sowing flasks for biochemical work; (4) tendency to form precipitates in Yeastrel milk agar if the pH is not carefully adjusted. These difficulties are not serious and can in most instances be overcome.

The general conclusions from tests on the most recent batches of Gigartina agar are that it is quite useful for routine work, but in the preparation of media attention must be paid to the main properties in which Gigartina agar differs from Japanese agar, viz. the higher setting temperature, the tendency of pour-plates and slopes to exclude moisture, and the use of an optimum concentration of 2.5-3.0%.

APPENDIX II

LIST OF SURVEYORS

ENGLAND AND WALES

ANGLESEY	V. Kohler (<i>Oxford</i>) L. Newton (<i>Aberystwyth</i>)	GOWER PENINSULA	D. Richards (<i>Aberystwyth</i>)
LLEYN PENINSULA	L. Newton	SOUTH WALES	E. R. Davies L. Newton
CARDIGAN BAY	E. A. Lewis (<i>Aberystwyth</i>) W. G. Loyn (<i>Aberystwyth</i>)	CORNWALL, DEVON AND DORSET	P. W. Carter (<i>Aberystwyth</i>) E. H. Chater (<i>Aberystwyth</i>)
PEMBROKESHIRE	E. R. Davies (<i>Aberystwyth</i>) L. Newton	NORTHUMBERLAND	A. D. Hobson (<i>Newcastle-on-Tyne</i>)

APPENDIX II *Continued*

LIST OF SURVEYORS

SCOTLAND

SOUTH-EAST SCOTLAND: R. M. Adam (*Edinburgh*)

WEST SCOTLAND:

NORTH OF THE FIRTH OF LORNE

SKYE AND INSHORE ISLES	R. M. Adam
	H. R. Fletcher (<i>Edinburgh</i>)
MULL AND INSHORE ISLES	W. Ingram (<i>Cambridge</i>)
	B. Kohler (<i>Oxford</i>)
	V. Kohler
	E. A. Lewis
	L. Newton
	C. A. Pratt (<i>London</i>)
	D. Richards
	D. M. Simpson (<i>Cambridge</i>)
	R. Williams (<i>Aberystwyth</i>)

SOUTH UIST	}	V. Kohler
BENBECULA		
COLL		
TIREE		
GUNNA		

WEST SCOTLAND:

SOUTH OF THE FIRTH OF LORNE

Clyde sea-area:

LOCH LONG AND LOCH GOIL	E. Conway (<i>Glasgow</i>)
	S. M. Marshall (<i>Millport</i>)
	A. P. Orr (<i>Millport</i>)

GARELOCH	E. Conway
	S. M. Marshall
	A. P. Orr

ARGYLLSHIRE, FROM TOWARD OLD QUAY TO DUNOON PIER	E. Conway
	E. T. Smillie (<i>Glasgow</i>)

KINTYRE, FROM ARDRISHAIG TO MACHRIHANISH	E. Conway
	G. S. Conway (<i>Glasgow</i>)
	S. M. Marshall
	A. P. Orr

AYRSHIRE, FROM INVERKIP TO ARDROSSAN	S. M. Marshall
	A. P. Orr

AYRSHIRE AND WIGTOWNSHIRE, WRIGHT'S ISLAND TO BURROW HEAD	E. A. Lewis
	C. I. Dickinson (<i>Kew</i>)

WEST SCOTLAND:

SOUTH OF THE FIRTH OF LORNE (*contd.*)

Islands of the Clyde sea-area :

BUTE	E. Conway
	S. M. Marshall
	A. P. Orr
	E. R. Trueman (<i>Glasgow</i>)

INCHMARNOCK	S. M. Marshall
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GREAT CUMBRAE	E. Conway
	S. M. Marshall
	A. P. Orr
	E. R. Trueman

WEE CUMBRAE	E. Conway
	S. M. Marshall
	A. P. Orr

ARRAN	E. Conway
	S. M. Marshall
	A. P. Orr
	G. Bullock (<i>Glasgow</i>)

Mainland coast:

KINTYRE, FROM MACHRIHANISH TO LOCH SWEEN (SOUTH SIDE)	S. M. Marshall
	A. P. Orr

LOCH SWEEN TO OBAN	S. M. Marshall
	A. P. Orr

Inshore islands:

GIGHA	E. Conway
	E. T. Smillie

LUING, SEIL AND EASDALE	S. M. Marshall
	A. P. Orr

Offshore islands:

ISLAY	E. Conway
	E. T. Smillie
	S. M. Marshall
	A. P. Orr

JURA	S. M. Marshall
	A. P. Orr

COLONSAY AND ORONSAY	S. M. Marshall
	A. P. Orr

APPENDIX III

SURVEY TABLES

APPENDIX III

SURVEY TABLES

TABLE I: ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
	ISLAND OF SKYE (surveyed July and August 1943). <i>Portree area.</i>	2					
Gigartina	½ mile S. of Prince Charles' Cave to Rudha na h'Airde Glaise.		1,600	10 to 20	5 lbs./lin. yd.	8,000	Occurs in <i>Fucus serratus</i> zone and among Himanthalia. Material large and free from epiphytes. Can only be collected at L.W.O.S.T.* Accessible only by boat.
Gigartina 90% Chondrus 10% }	Rudha na h'Airde Glaise to Sgeir Mhòr.			Narrow			Boulder beach: aspect E. Chondrus and Gigartina growing on larger boulders, but not in harvestable quantity.
Gigartina 50% Chondrus 50% }	Sgeir Mhòr Point Rocks.			1 to 5	1 lb./lin. yd.	100	<i>General Note:</i> This type of coast appears to continue for some miles further N.
Gigartina	Portree to Tom Cave.						Weed dirty and not worth collecting. Aspect N.E. Not easily accessible from seaward side. Present, but only accessible by boat.
	Peinchorran, 1 mile N. of ferry.	2					Present but not worth collecting—(information supplied locally).
Gigartina 90% Chondrus 10% }	N. point of Balmeanach Bay, to within 50 yds. of cave region.						Present but not worth collecting. Aspect E.
do.	50 yds., as far as cave region.		50	2-10	1 lb./lin. yd.	50	Aspect N., in strong tidal flow. Easy access.
Gigartina 95% Chondrus 5% }	Round point of Dunan an Aisilidh and 440 yds. E. side of Camas a' Mhór-bheòil.		585	4	8 lbs./lin. yd.	4,680	Aspect N.E. and N.W., in strong tidal flow.
do.	W. side of Camas a' Mhór-bheòil.						Present but not worth collecting. Aspect W.
	N. from this point and Clach Dhubh rocks.						Aspect W. Weed said locally to be present in quantity. Probably best collected from a boat.
							<i>General Note:</i> In this area it would be necessary to work at very low tides to collect the weed effectively.

*L.W.O.S.T. Low watermark ordinary spring tides.

TABLE I (contd.): ISLAND OF SKYE

Gigartina and Chondrus } Gigartina 90% Chondrus 10% } Gigartina 90% Chondrus 10% }	East Trotternish area. Stenscholl R. to An Corran.		2	660	1	1 lb./lin. yd.	330	Present but not worth collecting. Aspect N.N.E.
	An Corran to Ob nan Ron.			300	4½	5 lbs./lin. yd.	1,500	Occurring from lower side of <i>F. serratus</i> zone to Laminaria zone. Boulder beach. Aspect N.E.
	Ob nan Ron reefs, near jetty.							Flat slabs, lavas and shales. Aspect N.W.—richest areas: aspect S.E.—poor. Between Fucus and Laminarias.
	Ob nan Ron to Rudha Garbhaig. Rudha Garbhaig to Kilt Rock.							Difficult of access. Perpendicular cliff. Inaccessible.
Gigartina 90% Chondrus 10% } Gigartina 95% Chondrus 5% }	Kildorais to Creag na h-Eiginn.		2	1,320	5	2 lbs./lin. yd.	2,640	Aspect E. Algae occur on small boulders extending to Laminaria zone, and among <i>F. serratus</i> .
	Creag na h-Eiginn to Sgeir nan Eathar Bàna.			50	20	20 lbs./lin. yd.	1,000	Inaccessible.
	Sgeir nan Eathar Bàna to Bogha Ruadh.							A very dense growth of Himanthalia in this area, among which Gigartina occurs.
	Port Gobhlaig.			1,200	3	2 lbs./lin. yd.	2,400	Aspect N. Occurs in zone bordering the Laminarias and among <i>F. serratus</i> .
<i>General Note:</i> Very good plants of Gigartina occur in these areas. Usually found among <i>F. serratus</i> , except when Himanthalia is also present.								
Gigartina 50% Chondrus 50% } Gigartina 50% Chondrus 50% }	Islands of Raasay, Fladday and South Rona. Raasay.		2	800	10	1 lb./lin. yd.	800	Forming a carpet on the larger pebbles of the shingle in the <i>F. serratus</i> - <i>F. vesiculosus</i> zone.
	Raasay House to Inverarish.			15	1-10	6 lbs./lin. yd.	90	Growing above the Himanthalia, on the edges of large flat rocks projecting into the bay. Easy access from road through the village.
	S. of the monument of Inverarish.			400 300		1 lb./lin. yd. 1 " "	700	On the large pebbles of the shingle; among <i>F. vesiculosus</i> and <i>F. serratus</i> . Easy access from road to pier.
	Suisnish pier to Eilean Tigh; E. coast of Raasay.							Material only present on rocky headlands, and often not in harvestable quantity. Inaccessible in most areas.
Gigartina do.	Eilean Tigh—W. coast. Fladday—W. coast.		2	1,760 1,500	1-2 2-4	1 lb./lin. yd. 2 lbs./lin. yd.	1,760 3,000	} Easily accessible by } In these areas there is an almost continuous belt of Gigartina mixed with <i>F. serratus</i> , and extending into the sub-littoral zone with Himanthalia.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	(Raasay)—N. of Ard an Torrain.	2	1,500	1-2	1 lb./lin. yd.	1,500	Material very large, free from epiphytes, and as it forms a carpet growth in places, collection would be very easy. Should be collected at L.W.O.S.T.
Gigartina	N. of Manish More, and S. for 1,000 yds.	2	1,800	1-2	1 lb./lin. yd.	1,800	Notes as above; these areas are also easily accessible by boat.
Gigartina	S. of Glam Burn to Holoman Is.		1,800	1-2	1 " "	1,800	
Chondrus	Four areas from N. to S.: (i) (ii) (iii) (iv)		3,000	2	1 " "	3,000	
			800	2	2 lbs./lin. yd.	1,600	
			3,000	2	2 " "	6,000	
Gigartina	Holoman Is.		150	3	3 " "	450	Among <i>F. serratus</i> and above the Laminarias; large and free from epiphytes. Collection would be possible from the shore.
Chondrus							
Gigartina	S. of Holoman Is. to Oskaig Point.		500	4	4 " "	2,000	On the rocks in the <i>F. serratus</i> zone and extending among the Himanthalia. The algae would only be accessible at L.W.O.S.T. Collection presents some difficulty as no one lives on S. Rona permanently. The island is reached by boat from Fladday or Raasay.
Chondrus	Two areas: (i) (ii)		700	2	2 " "	1,400	
Gigartina	S. of Oskaig Point.	2	1,200	4	1 lb./lin. yd.	1,200	General Note: Total wt. of carrageen available from the Islands of Raasay, Fladday and South Rona is 35,550 lbs. (15½ tons).
Chondrus	Headland opposite Raasay House.		400	3	1 " "	400	
do.	N. of Churchton Bay.		50	7	5 lbs./lin. yd.	250	
Gigartina	South Rona.	2					Easy of access. Present in harvestable quantities, but not estimated. Collected in large amounts by local people.
Chondrus	Acairseid Mhor.		1,800	3	3 lbs./lin. yd.	5,400	
Gigartina	Garbh Eilean and Eilean an Fhraoich.		1,800	1-2	1½ " "	2,700	
Gigartina	North Trotternish area.	2					
do.	South of Ru Chorachan.						
do.	North part of Camas Beag.						
do.	Ru Idrigil.						
do.	Camas Mor.						
do.	Cairidh Ghlumaig to Ru Meanish.						

TABLE I (contd.): ISLAND OF SKYE

	<i>Dunvegan area.</i> Loch Bay, pier to Bay River. Dunvegan Hotel to S. end of Fiadhairt. S. end, to N. end of Fiadhairt. N. end of Fiadhairt to Camas Bàn above Claignan.	2					Absent. Absent. <i>Ascophyllum Mackaii</i> abundant at first stream above saw-mill. Inaccessible, and not surveyed. Absent.
Gigartina and Chondrus do.	Skinidin to Uiginnish Point. Uiginnish Point. Uiginnish Pt. to Dunvegan Head:	2					Partly inaccessible. Some weed present in small quantity on the rocky reefs. Present but not in harvestable quantity. Partly inaccessible. Weed almost absent.
Gigartina do. do.	Husabost, S. headland. Husabost, N. headland. Boreraig, S. headland.		500 500 900	1-2 1-2 1-5	1½ lbs./lin. yd. 1 lb./lin. yd. 2½ lbs./lin. yd.	750 500 2,250	} Could be approached either from the shore or by boat. Difficult to estimate as the tide was poor; possibly more weed present than estimated. Easily accessible.
Gigartina do. do. do. do. do.	<i>Loch Pool-tiel, Oisgill Bay, and Moonen Bay.</i> E. side of Loch Pool-tiel, ¼ mile N. of ruin. W. side of Loch Pool-tiel. N. side of the pier in Loch Pool-tiel. Oisgill Bay. Moonen Bay.	2		1-2	2 lbs./lin. yd. 2 " " 2 " "	60 5,000	Growing on a projecting reef and perhaps present in harvestable quantity, but only possible to collect at L.W.O.S.T. Gigartina is collected here, but no actual survey was possible. Large plants growing in tufts and forming a fringe around the rocks, mixed with <i>F. serratus</i> and Himanthalia. Accessible by boat. Weed present and possibly worth harvesting. It is collected locally. Accessible only at Camas Bàn. Very little algal vegetation on the rocks, but there is a distinct zone of Gigartina found on the boulders among <i>F. serratus</i> .
Gigartina 50% Chondrus 50% do. Gigartina and Chondrus Gigartina	<i>Loch Bracadale area.</i> Loch Varkasaig. E. side of Loch na Faolinn. Roag Is. and its environs. W. side of Loch Caroy, from head to Cross-nish Pt. Camas Bàn to Vatten.	2					} Probably present in quantity. Tide not sufficiently low to make an accurate estimate possible. Probably present in quantity: said to be so by the local people. Growing like moss on rocks, too short to gather. This usually indicates a highly profitable zone lower down, though this was not observable. Gigartina present in a zone approx. 1 yd. wide, but not in sufficient quantities to be worth collecting. There are large quantities of Rhodomenia along the whole shore.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	Loch Bracadale area (contd.) Caroy River to Ose Pt.	2					Narrow fringe of Gigartina visible, which probably indicates the presence of a wide zone at greater depth. Information supplied locally confirms this.
Gigartina 40% Chondrus 60% }	S. of Ose Pt. for 400 yds.		400	1-20	1 lb./lin. yd.	400	Footpath from wood to shore. Material extends over a wide zone into the <i>F. vesiculosus</i> and <i>Ascophyllum</i> . Much of it is in pools and is rather short.
Gigartina	Headland S. of Glen Ose.		200	1-3	1 " "	200	On vertical rocks below Rhodymenia.
do.	Colbost Pt.		800	1-10	1½ lbs./lin. yd.	1,200	On the flat rock surfaces and vertical edges. Much of the material is in deep pools among the rocks near high water mark. The densest distribution is towards Sgeir Mhor.
Gigartina and Chondrus }	Ullinish Bay.						Present on the N. side of the bay, but towards the river the area is muddy and the weeds are absent.
Gigartina 90% Chondrus 10% }	Oronsay Is. N.W. and S.W. side. N.E. headland and bays.	2					Inaccessible.
do.	Boulder ridge between Oronsay and mainland.						Good quality weed, but growing sparsely in little tufts and not worth collecting.
Gigartina 90% Chondrus 10% }	Ullinish Pt. to Bracadale Pt.	2					Present but not worth collecting: only partly surveyed, but the coastline is of a uniform nature.
	Bracadale Pt. to Loch Beag.						Boulder beach: not surveyed. Carrageen probably absent.
Gigartina 90% Chondrus 10% }	Ard nam Gamhainn.	2	100	4-10	1 lb./lin. yd.	100	Rather scattered and growing among <i>F. serratus</i> .
do.	Ard nam Gamhainn, round an inaccessible headland to Ullinish.						Present, but very scattered and not worth collecting.
Gigartina 90% Chondrus 10% }	Harlosh Pt., E. side, from S. of Crossnish Pt. going S.	2					Present in pools, probably in quantity, but the zone could not be estimated owing to the state of the tide. As the reef edges are steep, the zone is probably narrow. <i>F. serratus</i> and <i>F. spiralis</i> much torn by waves. Nematode present.

TABLE I (contd.): ISLAND OF SKYE

Gigartina Chondrus	90% 10% }	Loch Bracadale area (contd.) Continuing S.	2			‡ lb./lin. yd.		Occasional zone 10 yds. wide, on shelving reefs. Accessibility easy to moderate: in deep water at the edges.
do.		Near and round Harlosh Pt.						Inaccessible.
do.		Harlosh Pt., W. side, going N.						Present but not worth collecting. Rather difficult of access, with steep edges and low cliffs. Inaccessible further N.
		Camas Bàn.						Absent.
Gigartina Chondrus	90% 10% }	Harlosh Island. Clockwise circuit of the island, starting from the northern sandy bay in which the weeds are absent.	2					Present but not worth collecting. Boulders with much Ascophyllum.
do.		Sides of bay.						Shelving rock with good material. Further E., present but not worth collecting: access difficult or impossible.
do.		E. of bay.		50	4	1 lb./lin. yd.	50	
do.		Small rocky bay on E. side.		100	10	1‡ lbs./lin. yd.	150	Large plants.
do.		S.E. end.						Inaccessible. High cliff, viewed from above.
do.		South Bay.						Present, but not worth collecting. Boulders.
do.		S. and W. coasts.						Inaccessible. High exposed cliff, seen from above.
do.		N.W. end.		50	5-10	1-2 " "	75	Large plants.
Gigartina		Tarner Island.	2					Inaccessible.
do.		West side.						Probably present in harvestable quantity; only accessible by boat.
do.		S.E. bay.						
do.		N.E. bay, from S. headland going N.						
		Three areas:						
		(i)		50	10	10 lbs./lin. yd.	500	Good clean weed on shelving rocks. Only accessible by boat.
		(ii)		50	3	1 lb./lin. yd.	50	Plants present among <i>F. serratus</i> .
		(iii)		200				Present but not worth collecting.
do.		N. headland.		50	1-3	1 " "	50	Present on rocky headland among <i>F. serratus</i> . Rocks falling away steeply below zone.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
	<i>Loch Bracadale area (contd.)</i>	2					
	<i>Wìay Is.</i>						Inaccessible; very steep cliffs.
	West side of island.						
Gigartina 90% } Chondrus 10% }	N. side of natural arch.		440	1-2	2 lbs./lin. yd.	880	On boulders on shelving shore in <i>F. serratus</i> zone.
do.	Cave region, N.E. of island.		880	1-3	2 " "	1,760	As above.
	<i>Minginish area.</i>	2					
Chondrus	(a) <i>Loch Harport</i> :						Very few plants on the shingle. Not worth collecting.
	Mouth of Sumardale burn.						Very few plants, on shingle that is washed by fresh water. Not worth collecting.
Gigartina	Mouth of small burn S. of Sumardale burn.						Only a few small plants observed; not worth harvesting.
do.	Mouth of Meadale burn.						<i>General Note:</i> The N. shore of the loch consists mainly of very fine shingle with a wide belt of <i>Ascophyllum nodosum</i> . Chondrus and Gigartina present only at the river mouths: confirmed by the local people.
do.	Fiskavaig Pt.		40	5	5 lbs./lin. yd.	200	On edge of reef.
	(b) <i>Loch Talisker</i> :	2					
Gigartina	Rudha Cruinn for 750 yds., into Talisker Bay.		750	2-5	2 lbs./lin. yd.	1,500	Weed growing thickly on large basalt boulders. At the head there is a series of reefs, accessible by boat, which would probably be a very rich source. This area, as a whole, is best reached by boat.
do.	S. shore of Talisker Bay.		100	2	1 lb./lin. yd.	100	Growing on boulders. Access is possible from the shore.
	Headland at Talisker Pt.		200	1-2	3 lbs./lin. yd.	600	Growing on reefs and shelving rocks, as well as in the rock pools. } These areas are best reached by boat.
Gigartina	Talisker Pt. to Biod Ruadh.		1,000	2-5	1 lb./lin. yd.	1,000	Growing on large basalt boulders.
							<i>General Note:</i> Collection in this area as a whole would best be done from a boat at L.W.O.S.T., and when the prevailing wind is not W. or S.W., as the waves then drive straight into the bay. The cliffs beyond the points actually surveyed are said to be very difficult of access.

TABLE I (contd.): ISLAND OF SKYE

Gigartina	Minginish area (contd.)	2	200	2-20	2 lbs./lin. yd.	400	Easy of access at one place only. Algae occur on flat, wide rock slabs with frequent Himanthalia and <i>F. serratus</i>; also above the Laminarias. Pure consociations frequent. Easy access from Grula. Weeds absent. Shingle, with little algal growth. Chondrus in upper pools and a little Gigartina under <i>F. serratus</i>. Not in harvestable quantities. Grows in a belt on the edges of the rocks; most dense in the gullies. Best reached by boat.
do.	(c) Loch Eynort: E. of Creagan Dubh. Shore W. of Creagan Dubh. Grula to Kraiknish. 300 yds. W. of Kraiknish. 1,000 yds. at Laimbrig na Moine		200	2-20	2 " "	400	
Gigartina Chondrus			1,000	2-3	1 lb./lin. yd.	1,000	
Gigartina	Headlands N. of Dun. Three areas: (i) (ii) (iii)	2	200 80 200	3-10 2 2	5-10 lbs./lin. yd. 1 lb./lin. yd. 10 lbs./lin. yd.	1,000 80 2,000	Access difficult from the shore. Forms a distinct band between <i>F. serratus</i> and the Laminarias, and is frequently associated with Himanthalia. Difference in density due to the variation in width of the rocky ledges. Collection should be done at L.W.O.S.T. N. of Dun the shore is composed of fine shingle and Gigartina is absent.
Gigartina							
Gigartina							
do.	(d) Loch Brittle: From N. end, down E. side for two miles. 1 mile N. of Rudha 'an Dunain (at foot of water-fall). From waterfall to end of Loch (Rudha 'an Dunain). Dun Sgeir Mhor. N.W. coast, S.W. from first burn. Continuing, towards Geodha Daraich. Mouth of 2nd burn. 2nd burn to Sgurr Brittle.	2	3,520 (2 miles) 200 1,800 880 50 700 3 900	2-10 30 3-5 3 10 3-10 20 1-3	4 lbs./lin. yd. 15 " " 2½ " " 2 " " 6 " " 2-5 " " 12 " " 2-5 " "	14,000 3,000 4,500 1,760 300 2,500 36 3,500	Abundant on all rocky outcrops in the <i>F. serratus</i>-Himanthalia zone and higher. A wide zone on gently sloping flat slabs. Forms a carpet on boulders and in gullies. Not very easy of access. Wide foreshore backed by steep cliffs. Difficult of access. Abundant among <i>F. serratus</i>. Easily accessible by boat. Occurs among <i>F. serratus</i> and Himanthalia; at times as a pure consociation. Well developed, occurring on face of boulders facing cliff. As above, and extending also into the stream bed. Occurring on boulders and as a narrow zone on steeply sloping reefs. Access less easy.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	Minginish area (contd.)	2	1,300	2	2 lbs./lin. yd.	2,600	Present among <i>F. serratus</i> and Himanthalia. } Present on steeply sloping rock, among <i>F. serratus</i> and Himanthalia. } This whole area easily accessible by boat.
do.	(e) Loch Scavaig and Soay:		440	4	4 "	1,760	
do.	N. of Rudh' a' Gheodha Bhuide to Eilean Reamhar.		700	2	2 "	1,400	
do.	Eilean Reamhar to island.		1,100	2	2 "	2,200	
do.	S. of Scavaig River to beyond headland.		220	2	2 "	440	
	S. of Port Sgaile to N. of Rudha Buidhe.						
	E. of Rudha Buidhe.						
Gigartina	Strathaird to Sleat.	2				15	Forming a carpet on one or two boulders, under <i>F. serratus</i> at mid-tide level. Easy access from shore near school. Not in harvestable quantity.
do.	‡ mile N. of Elgol, near small house.						
do.	From above point to just N. of school.						
Gigartina	From N. of school, for 400 yds. S.		400	1	1 lb./lin. yd.	400	Under <i>F. serratus</i> ; Chondrus found at a higher level than Gigartina.
Chondrus	In bay immediately E. of Prince Charles' Cave.					24	On a sandy spit in the middle of the bay, under <i>F. serratus</i> . Easy access from the cliffs.
Gigartina	On rocks projecting from Strathaird Pt.		50	10	10 lbs./lin. yd.	500	Forming a carpet under <i>F. serratus</i> and almost completely covered by its thalli. Easy access from bays beyond the cave.
Chondrus	Camas Malag S. of Torran, round the head of Loch Slapin to Faodean.	2	4,840 (2½ miles)	5	2½ lbs./lin. yd.	12,100	Carrageen absent from the whole of this area.
	From Faodean to Spar Cave.						Chondrus, with a few scattered Gigartina plants, occurs along the whole length of this shore, in the <i>F. serratus</i> zone. With the exception of the locality below, it averages 2½ lbs./lin. yd. Easy of access at Faodean and Kilmarie, but foreshore difficult.
do.	For 200 yds. S. of Rudha Cruaidhlinn.		200	30	15-20 "	3,000-4,000	Occurs in a wide zone, varying between the type species and the deep water variety. Easy access from foreshore.
Chondrus	Camas Malag Bay.	2				250	Under <i>F. serratus</i> and immediately above the Laminarias. Not worth harvesting.
Chondrus	Camas Malag Bay to Stac Suishnish.		3,000	1-2	1 lb./lin. yd.	3,000	On boulders under <i>F. serratus</i> and around the holdfasts of Laminarias. Boulders do not form a continuous belt.

General Note:

Material could only be collected for one hour before and after L.W.O.S.T.

TABLE I (contd.): ISLAND OF SKYE

Gigartina	Strathaird to Sleat (contd.) From Stac Suishnish to $\frac{1}{4}$ mile N. of Calaman Cave.	2	55	10	7 $\frac{1}{2}$ lbs./lin. yd.	412	Occurring among <i>F. serratus</i> ; densest at lowest points of 10 yd. zone. Verges on Laminarias. Easily accessible from Suishnish.
Chondrus	Pools opposite Calaman Cave.		40	40	60 lbs./lin. yd.	2,400	In pools and under surrounding <i>F. serratus</i> .
do.	Pool opposite headland S. of Calaman Cave.		30	40	40 "	1,200	" " "
Gigartina	Calaman Cave (just N.) to mouth of burn S. of Suishnish.		1,200	10	20 "	24,000	Under <i>F. serratus</i> . Densest in lower part of zone.
Chondrus							
Gigartina	Boreraig Bay, Loch Eishort W. of waterfall.		1,800	2-10	5 lbs./lin. yd.	9,000	Most easily accessible by boat, probably from Heast.
Chondrus							
Gigartina							Habitats:
Chondrus							(a) in upper pools and in fresh water running into the bay;
							(b) Gigartina forms a carpet at edge of <i>F. serratus</i> zone, especially abundant on the edges of the rocks;
							(c) a small amount of Chondrus among Himanthalia.
							Collection to be made only at L.W.O.S.T.
Gigartina	Ord to 100 yds. N. of Rudh Dubh Ard.	2	1,000	1-3	1 lb./lin. yd.	1,000	Aspect N.E. Growing on small boulders and small reefs.
Chondrus	100 yds. E. of Ord River to Inver Aulavaig.		1,000	1-3	1 "	1,000	Aspect N.N.E. Under <i>F. serratus</i> , above Laminarias. Growing on boulders and small reefs.
do.	Inver Aulavaig to Ob Gauscavaig.		60	1-3	1 "	60	As above.
do.	Centre of Ob Gauscavaig Bay.		1,760	1-3	1 "	1,760	As above.
do.	Ob Gauscavaig Bay to within $\frac{1}{4}$ mile of Tarskavaig Pt.						As above.

General Note for this area:

Gigartina occurs in a 10 yd. zone extending from beneath *F. serratus* to the Laminaria belt. Zone only exposed for one hour before and after low water of good spring tides. Chondrus occurs in pools in the upper part of the zone, on the wide headland.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina Chondrus	Sleat area. Tarskavaig Point.	2	880	1-6	3½ lbs./lin. yd.	3,300	Aspect due W. and S. Between <i>F. serratus</i> and <i>Laminarias</i> ; some of the material under thalli of <i>Fuci</i> . Accessible only at L.W.O.S.T. <i>General Note:</i> From the S. headland of Tarskavaig Bay round the Point of Sleat to the Aird of Sleat the coast is inaccessible and no survey was possible. Almost pure <i>Gigartina</i> on the rocks in the <i>F. serratus</i> zone. Wherever fresh water runs in, areas of <i>Chondrus</i> with weights of between 300-500 lbs. are established on rocks and in rock pools. Fresh water running in at intervals. <i>Chondrus</i> forming mossy patches on rocks near streams and in rock pools. Well marked belt in <i>F. serratus</i> zone, among and between these plants. <i>Gigartina</i> re-established where area free from fresh water.
Gigartina	Shore opposite Aird of Sleat to Ferindonald.		17,600	5	5 lbs./lin. yd.	88,000	
Chondrus	Shore opposite Ferindonald to opposite Saasaig.			5	1 lb./lin. yd.	2,650	
Chondrus	Ornsay area. From head of Loch na Dal S. for ¼ mile.	2					Present but not in harvestable quantity. Very sparse, chiefly high up in rock pools with <i>F. vesiculosus</i> . Weed contaminated with <i>Leathesia</i> and not worth collecting. Easy of access at first, but more difficult on steep rocks later.
do.	For ¼ mile to mouth of burn: two areas: (i)		900	4	2 lbs./lin. yd.	1,800	Aspect N.E. Weed usually contaminated when exposed, but clean under <i>Fucus</i> . Difficult of access.
do.	(ii) From burn to Camas a' Mhuilt.		15 400	6 1	6 1 lb./lin. yd.	90 400	Weed contaminated badly with <i>Leathesia</i> . Aspect E. Easy climbing over rock to reach zone. <i>Rhodomenia palmata</i> mixed with <i>Chondrus</i> ; otherwise clean and possibly worth collecting.
do.	From Camas a' Mhuilt to N. coast of Ornsay.						Present but not in harvestable quantities and, where it is more abundant, access is very difficult.
Gigartina	S.E. corner of Isle Ornsay and Eilean Sionnach.		440	3	4½ lbs./lin. yd.	1,980	Occurring among <i>F. serratus</i> . Only to be reached at very low spring tide, or by boat.

TABLE I (contd.): ISLAND OF SKYE

APPENDIX III: SURVEY TABLES

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Ornsay area (contd.)		2	2,000	5	5 lbs. lin. yd.	10,000	Under <i>F. serratus</i> . L.W.O.S.T.	Accessible only at
Gigartina	S.W. corner of Ornsay round Ard Ghunel to Camas Croise.		2,000	5	5 lbs. lin. yd.	10,000		
do.	Camas Croise to Knock Bay.		6,000	3-7	5 "	30,000		
Chondrus	Broadford area to <i>Kylerhea</i> .	2						Present, but not in harvestable quantity.
Gigartina and Chondrus	Broadford New Pier to Rudh'an Eireannaich.							
	From there for 400 yds. to the N.W.		5	20	20 lbs. /lin. yd.	100		
	(i) Headland		400	3	3 "	1,200		} More Gigartina than Chondrus.
	(ii) Remainder							Present, but not worth collecting.
do.	Coast as far as Rudha na Sgianadan.				‡ lb. /lin. yd.			
do.	Camas Sgianadan.							
Chondrus	On to mouth of first burn.							Present, but not in harvestable quantity.
	Mouth of first burn.		6		35 lbs. /lin. yd.	210		Stream bifurcates: one channel contains Chondrus, the other is full of <i>Ascophyllum Mackaii</i> .
Gigartina and Chondrus	From mouth of first burn to mouth of fourth burn (road bridge).							Present, but not worth collecting.
								<i>General Note:</i> The whole of the coast from the Pier to this point is easily accessible and has shallow shelving rocks, bearing Fuci and Laminarias in the deeper water. A northerly aspect is associated with a comparative absence of carrageen. As there is no apparent change in the coast westwards, it would appear that there is no change in the distribution for at least 2 miles.
Gigartina	Broadford: W. of Old Pier.	2						Occurs in stream in small quantities.
Gigartina and Chondrus	Broadford: S.E. of Old Pier.							Growing with <i>Laurencia</i> , among <i>F. vesiculosus</i> and <i>Ascophyllum</i> . Gigartina plants very small.
Chondrus	Bed of burn in Broadford Bay.		2	30	26 lbs. /lin. yd.	52		Above mid-tide level.
Gigartina Chondrus 50% 50% }	Point just E. of mouth of burn.		50	4	2 "	100		On rocks at low water mark.
do.	From here along the coast, eastwards to Kyleakin.							Sparsely distributed: not in harvestable quantities. In most cases the material grows among the larger brown algae and is often difficult to find without removing the overlapping thalli.

TABLE I (contd.): ISLAND OF SKYE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina and Chondrus do.	<i>Broadford area to Kylerhea (contd.)</i> Rudha na Caillich to 1 mile S. of Kylerhea. 100 yds. S. of Kylerhea Pier.	2	100	1	1 lb./lin. yd.	100	Present, but not in harvestable quantity. Aspect N.E. Strong tides sweep down the Sound on the ebb. Rather difficult of access. Quantity probably not worth collecting, but is mentioned because the weed was found to grow more densely where the current was strongest.
Gigartina and Chondrus	<i>Sligachan and Scalpay area.</i> Scalpay. Rudha Doire na Boceinain, nearly to Rudh' an Lochain.	2	100	5-10	1 lb./lin. yd.	100	Not easily accessible. Weed growing sparsely in tufts on sloping reefs: not in harvestable quantity. As above, but this small quantity is easily collectable. As above: not in harvestable quantity. Sandy beach. Weed absent. Growing in places on very small pebbles: not harvestable. Absent. Growing in places on very small pebbles: not harvestable.
do.	On Rudh' an Lochain.				1 lb./lin. yd.	10	
do.	Rudh' an Lochain, to Rudh' a Chinn Mhoir.						
Gigartina	Camas na Geadaig Bay.						
do.	Rudh' a' Channaidh, S. for $\frac{1}{2}$ mile.						
do.	From this point to Rudha Reireag.						
do.	Rudha Reireag to Corran a' Chinn.						
do.	S. side of Corran a' Chinn.						
do.	River Corrie Uaghdaich to Slignbach.						
Gigartina and Chondrus	Sgeir Stapaig.						<i>Ascophyllum Mackaii</i> present: Gigartina not in harvestable quantity.
Gigartina 90% Chondrus 10%	River E. of Sgeir Stapaig to Rudh' an Torr Mhoir.						Absent.
Gigartina 75% Chondrus 25%	Rudh' an Torr Mhoir headland.						Present chiefly on small reefs and areas with fresh water: not in harvestable quantity.
do.	N. of Rudh' an Torr Mhoir. Two areas: (i) (ii)						Dense zone on the headland.
do.	N. of Camas nan Uisgeachan. Three areas: (i) (ii) and (iii)						Gigartina occurs as a distinct belt between <i>F. serratus</i> and the Laminarias. It usually grows on the vertical edges of the rocks, densest in the gulleys.
							On rocky promontories, often mixed with Himanthalia.

TABLE I (contd.): ISLAND OF SKYE

TOTAL WEIGHT FOR SKYE IS 146 TONS.

TABLE II: ISLAND OF MULL

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT			NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	
	ISLAND OF MULL (surveyed August 1943). <i>N. Mull. Ulva Sound to Sorne Pt.</i> <i>Ulva Sound to N. side of Laggan Bay.</i>	3				Absent. <i>Ascophyllum nodosum</i> tufts on shingle shore. Easily accessible by boat.
Gigartina and Chondrus	Two headlands N. of Laggan Bay.					Present on reefs running out from the shore but not worth collecting. Easily accessible by boat.
do.	Camas an Lagain. Alt an Eas Fors to S. pt. of Ballygown Bay.					Shingle. Weeds absent. Collected locally from reefs running out from the shore. Easy of access by boat.
do.	Ballygown Bay. Ballygown Bay to Traigh na Cille.					Shingle and sand. Weeds absent. Collected locally and probably present in fair quantity. Easy of access by boat.
do.	Traigh na Cille Bay.					Sand. Weeds absent.
do.	Traigh na Cille Bay, E. to Rudh' an t'Suibhein.					Collected locally and said to be a good area.
do.	Rudh' an t'Suibhein to Treshnish Pt.					No definite information available but rock formation looks suitable. Easy of access by boat, and probably present in harvestable quantity.
do.	Treshnish Pt. to Calgary Bay.					Collected locally and said to be a good area.
do.	Head of Calgary Bay. Calgary Bay over Rudha nan Oirean to Port a'Phartain.					Sand and boulder beach. Weeds absent. Easy of access by boat. Said to be excellent; probably present in harvestable quantity.
do.	Port a'Phartain. Caliach Pt. to ¼ mile W. of Rudha an Ard.					Inaccessible.
Gigartina 90% Chondrus 10% }	¼ mile W. of Rudha an Ard to ¼ mile E. of Port na Ba.		600	2-10	2 lbs./lin. yd.	Easy of access by boat. Probably present in harvestable quantity. Said to be very rich, especially in Laggamull Bay.
do.	¼ mile E. of Port na Ba to W. entrance of Loch Cuan. L. Cuan to Poll Athach.				1,200	Weeds growing on lava platforms running from under basalt cliffs. Difficult of access, but easy by boat. Present but not worth collecting.
						Weeds absent. Mud with <i>Ascophyllum nodosum</i>

TABLE II (contd.): ISLAND OF MULL

Gigartina and Chondrus	} do.	N. Mull. Ulea Sound to Sorne Pt. (contd.)	3				Present but not worth collecting.	} Easy of access by boat.
		Poll Athach to Alltantaibh.					Probably present in harvestable quantity. Said to be very rich.	
Gigartina and Chondrus	} do.	Alltantaibh over Quinish Pt. to Loch Mingary.	3				Mud; weeds absent.	} Easy of access by boat.
		Loch Mingary.					Probably present in harvestable quantity. Said to be excellent. Easy of access by boat.	
Gigartina and Chondrus	} do.	N. Mull. Sorne Point to Tobermory.	3				Present but not worth harvesting. Large reefs running out from under basalt cliffs.	} Easy of access by boat.
		Sorne Pt. to Port Chill Bhraondin.					Said to be present in harvestable quantity. Shore as above.	
do.	} do.	Thence ½ mile E.	3				Present but not worth harvesting. Not easy of access; best by boat.	} Easy of access by boat.
		Thence to Ardmore Bay.					Said to be present in harvestable quantities. Not easy of access; best by boat.	
do.	} do.	Ardmore Bay.	3				As above.	} Easy of access by boat.
		Rudha-nan-Gall Lighthouse.					Inaccessible.	
do.	} do.	Ardmore Pt. to Tobermory.	3				Said to be present; probably in harvestable quantity.	} Easy of access by boat.
		N. Mull. Sound of Mull.					As above: Himanthalia seen, which is usually an indication of the presence of Gigartina.	
Gigartina	} do.	Ardnacross to Kintalkn.	3				Present but not worth harvesting.	} Easy of access by boat.
		Kintalkn to Rudha Ard Ealasaid.						
do.	} do.	Rudha Árd Ealasaid to Aros Castle.	3					

TABLE II (contd.): ISLAND OF MULL

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Chondrus	N. Mull. Sound of Mull (contd.) Salen Bay. River Aros to Salen Hotel.	3					Shore rather muddy, with <i>Ascophyllum</i> <i>Mackaii</i> present; <i>Chondrus</i> in small quantity on the reefs; not worth collecting. <i>General Notes:</i> This part of the survey is based largely on local information for, with the exception of Rudha an Ard, no investigation was possible owing to the state of the tides. There is a great scarcity of local labour, though this might be obtained in the Langamull Bay and Mingary regions, and there seems some possibility of getting the seaweed away via Tobermory. Also, there are very few boats available, and the exposure of the coast would probably make collection difficult on many days during the harvesting period.
Gigartina and Chondrus do. do.	Salen to Loch Don area. (a) Craignure to Loch Don: Craignure to Duart Pt. Duart Pt. to Gorten Pt. Duart Pt. and Islands off the point, to Loch Don. Loch Don. Grass Pt. to Rudha na Faolinn, excluding Port Donain.	3					Absent. Present but not worth collecting. Said to be present in moderate quantity. Easy of access by boat. Information supplied locally. Absent. Mud with <i>Ascophyllum nodosum</i> . Said to be present in moderate quantity. Easily accessible by boat.
Gigartina and Chondrus do.	(b) Craignure to Salen: Java Pt. to golf course. Golf course to Garmony Pt.	3					Present on upper rocks but not worth collecting. Not properly surveyed owing to state of tides. Shore conditions favourable; <i>Ascophyllum nodosum</i> absent and <i>Himanthalia</i> present. Present, except in the shingle bays. Not worth collecting.

TABLE II (contd.): ISLAND OF MULL

Chondrus	<i>Craignure to Salen (contd.)</i> 1 mile S. of Rudha Leth Thorcuill to Fishnish Bay.	3					Present but not worth collecting. Difficult of access. Absent. Absent. Inaccessible. Present but not worth collecting. Poor growth; in rock pools. Absent. Fine shingle with very little algal growth. Present but not worth collecting.
do.	Fishnish Bay. Rudha na Leitreach, for 1 mile W. Thence to Glen Forsa House. Glen Forsa House to Rudha nam Buth. Rudha nam Buth to Salen.						
Gigartina and Chondrus }	<i>Loch Buie and Loch Spelve areas.</i> Laggan Lodge to beyond Rat Island, and including the island. Loch Spelve.	3					Said, by the local people, to be present in harvestable quantity. Easily accessible. Carrageen absent.
Gigartina	<i>Ross of Mull area.</i> Bunessan Bay. Traigh Mor to Rudh' nam Buthan. Rudh' nam Buthan to W. headland of Bay. Thence to Camas Tuath.	3					Absent. Present but not worth collecting. Information supplied locally. Probably present in harvestable quantity. Access easy by boat. Information supplied locally. Growing on the granite reefs. Sand at head of bay. Inaccessible. Probably present in harvestable quantity. Access easy by boat. Information supplied locally. Inaccessible. Collected locally. Probably present in harvestable quantity. Present but not worth collecting. Information supplied locally. Easy of access by boat. Collected locally. Probably present in harvestable quantity. Easy of access by boat. Absent. Sand.
do.	Camas Tuath Bay, excluding extreme end.		880	2-5	1 lb./lin. yd.	880	
do.	Camas Tuath to Cnoc Mor. Two small bays W. of Cnoc Mor.						
do.	Rest of N. coast to Rudha nan Ceare. Rudha nan Ceare to Dearg Phorts. Dearg Phorts to Slugan Dubh.						
do.	Slugan Dubh to Erraid Sound. Erraid Sound.						
do.	Erraid Islands, except Erraid Sound.						Probably present in harvestable quantity. Easy of access by boat. Information supplied locally.

TABLE II (contd.): ISLAND OF MULL

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina and Chondrus	Ross of Mull area (contd.) Knockyologan to Torr Mor.	3					Present but not worth collecting. Easy of access by boat. Information supplied locally.
do.	Torr Mor and Eilean a'Chalmain.						Probably present in harvestable quantity. Collected locally, especially on the island. Easy of access by boat.
do.	Torr Mor to Conarst. Conarst to W. headland of Ard Mor.						Inaccessible. Steep cliffs. Probably present in harvestable quantity. Easy of access by boat. Information supplied locally.
do.	Thence to Rudha nam Maol Mora. Thence to Ard Dhugaill and Eilean Mor. Thence to Sgeireig a'Bhochdaigh.						Inaccessible. Probably present in harvestable quantity. Easy of access by boat. Information supplied locally. Inaccessible. Steep cliffs.
							<i>General Notes:</i> Any collecting along the coast S. and E. of Erraid to Sgeireig a'Bhochdaigh must be done by boat and would be difficult as the shore is very rugged and exposed to the Atlantic swell. The weed is stated to be much torn about on this exposed coast and is likely to be of poor quality.
Gigartina and Chondrus	Rudh' Ardalanish to Ardalanish Bay.	3					Probably present in harvestable quantity. Easy of access by boat. Local information.
	Ardalanish Bay.						Absent. Sand.
Gigartina 95% Chondrus 5% }	Ardalanish Bay to Uisken (including reef and island).		1,760	2-10	2 lbs./lin. yd.	3,250	Excellent growth and easily harvested. Much used by local people.
Gigartina and Chondrus	Uisken to Aoineadh Beag including reefs. Aoineadh Beag to Carsaig Arches.						Probably present in harvestable quantity. Said to be similar to Uisken. Rock formation similar. Inaccessible.
							<i>General Note:</i> Local information suggests that the weed is less plentiful on granite.

TABLE II (contd.): ISLAND OF MULL

Gigartina and Chondrus	Ross of Mull area (contd.) Carsaig Arches to headland W. of Carsaig Bay. W. and E. headlands of Carsaig Bay and reefs off latter. Thence to Rudha Dubh.	3				Said to be inaccessible. Probably present in harvestable quantity. Easy of access by boat. Beach, where present, has boulders. Long reefs running out from basalt cliffs. Information supplied locally. Said to be inaccessible. <i>General Note:</i> There is the usual labour shortage in this area, and there are only two row-boats, both of which are fully occupied in fishing.
	Loch Scridain area. Tioran to Pennyghael. Pennyghael to $\frac{1}{4}$ mile W. of Port na Cloidheig. Thence to Goirtoin Driseach. Goirtoin Driseach to Ard Fada. Ard Fada to Ormsaig. Ormsaig to Loch na Carra. Loch na Carra. Loch na Carra to Rudha Breac. Rudha Breac to Traigh Mhor.	3				Absent. <i>Ascophyllum nodosum</i> present in large quantities. <i>Ascophyllum Mackaii</i> and <i>Fucus ceranoides</i> present where rivers reach the shore. Easy of access from the road. Probably present but not worth collecting. Information supplied locally. Easy of access from the road. Probably present in harvestable quantity. Local people collect the weed and supplied this information. Labour is very scarce in the Pennyghael area. Probably present in harvestable quantity. Absent. Boulders. Probably present in harvestable quantity. Absent. Shingle. Probably present in harvestable quantity. Difficult of access but easy by boat. Collected locally and said to be as good, especially at Eilean na Duhlish near Na Fairchean, as at Uisken (Ross of Mull). Said to be present but not worth collecting.

TABLE II (contd.): ISLAND OF MULL

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina and Chondrus do.	Loch Scridain area (contd.) Sgeirr na Faolinn to Carraig Mhic-Thomaia. Carraig Mhic-Thomaia to $\frac{1}{4}$ mile E. of Burgh. $\frac{1}{4}$ mile E. of Burgh to Port na Croise.	3					Inaccessible. Said to be present but not worth collecting. Probably present in } Local information. harvestable quanti- ties. Absent.
	Port na Croise.						
Gigartina and Chondrus 90% } 10% }	Loch na Keal area. (a) South shore: River Ba to Rudh' a' Ghearrain. Coast opposite Salaman Is. to Rudha Baile na h'Airde. Rocks opposite Rudha Baile na h'Airde and for $\frac{1}{4}$ mile S.	3					Not worth collecting. Shore largely com- posed of small reefs and boulders. <i>A.</i> <i>nodosum</i> very abundant in wide zones, up to 50 yds. Absent. Shore sandy, with little algal vegetation. Growing on edges of level rocks. Some Gigartina in the <i>F. serratus</i> zone, and also with Himanthalia. Chondrus growing at greater depth. Accessible by boat and by onshore reefs.
	Gribun. Rocks opposite Bogha nan Cruban.		500	2-10	1 lb./lin. yd.	500	Growing on edges of level rocks. Some Gigartina in the <i>F. serratus</i> zone, and also with Himanthalia. Chondrus growing at greater depth. Accessible by boat and by onshore reefs.
	Coast opposite Balmeanach for 300 yds.		500	2-10	1 lb./lin. yd.	500	Growing on edges of level rocks. Some Gigartina in the <i>F. serratus</i> zone, and also with Himanthalia. Chondrus growing at greater depth.
	S. of Balmeanach to Rudha na h'Uamha.		300	1-2	1 " "	300	Chondrus in upper pools and Gigartina on the edges of the rocks in the <i>F. serratus</i> zone: growing where fresh water enters the bay. Inaccessible.
Gigartina and Chondrus 60% } 40% }	(b) North shore: River Ba to Kellan. Kellan to Rudha Mor. Rudha Mor to $\frac{1}{4}$ mile E. of Ard Dearg.	3					Absent. <i>Ascophyllum nodosum</i> dominant. Absent. <i>A. nodosum</i> present. Occurring chiefly in rock pools but not worth collecting. Not easy of access.

TABLE II (contd.): ISLAND OF MULL

		3				
Gigartina and Chondrus	<i>Ulva</i> and <i>Gometra</i> area.					
	E. side of Sound of Ulva.					
	Islands in Sound of Ulva.					
	<i>Ulva</i> .					
Gigartina and Chondrus	W. side of Sound of Ulva, from headland up to Port Gharb.					
	Round the head of Port Gharb.					
	N. shore of Ulva, from Port Gharb to E'n a Choire.					
	Sound between Gometra and Ulva.					
Gigartina and Chondrus	S. shore of Ulva opposite Gometra for 500 yds. E.	1,760	Up to 200	2 lbs. /lin. yd.	3,520	
	Brionn Phonn to Traigh Ban, including island.					
	Traigh Ban to E'n nan Beilgun.					
	E'n nan Beilgun to Torr Mor.					
do.						
Gigartina and Chondrus	Headland below A'Chrannag.					
	<i>Gometra</i> .					
	Dun Ban to Rudha a Mhill Mhoir and round to Soilean Mor.					
	Headland of Rudha Bhrisdeadh ramh.					

TABLE III: CLYDE SEA-AREA
(a) LOCH LONG, LOCH GOIL AND THE GARELOCH

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT			NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.
Gigartina	LOCH LONG, LOCH GOIL AND THE GARELOCH (surveyed July 1942). <i>Loch Long. W. side to Loch Goil.</i> Blairmore Pier to Blairbeg burn.	4	1,600	1-5	2 lbs./lin. yd.	3,200 +150
do.	Blairbeg burn to Gairletter Point.		1,700	4	½ lb./lin. yd.	850
Gigartina	Round burn just S. of B.M. 26·8.	4	100 sq. yds.		2 lbs./sq. yd.	200
do.	Round burn Allt Fuilnan Sgalag.		50	4-5	9 lbs./lin. yd.	450
do.	Round Ardentinn burn.		200	4-5	2 " "	400
do.	Sandy bay S. of Ardentinn Pt. to Ardentinn Pt.		25		1-2 " "	40
do.	Round Ardentinn Pt.		75		3-4 " "	250
do.	Ardentinn Hotel to N. of jetty.		200		½ lb./lin. yd.	100
do.	N. of jetty (50 yds.) to schoolhouse burn.		100	3	1-2 lbs./lin. yd.	150
Gigartina	Shepherd's Pt. to Port Dornaige.	4	1,700	½-1	1 lb./lin. yd.	1,700
Gigartina	Knap Bay round S. burn (Allt Uambach a'Bheithe).	4	25		2 lbs./lin. yd.	50
Gigartina	<i>Loch Goil.</i> Round burn about 200 yds. N. of Oakbank Cottage.	4	30	4-5	6 lbs./lin. yd.	180
Gigartina	S. of burn entering at Lochwood.	4	50 sq. yds.		1-2 lbs./sq. yd.	75
do.	S. of burn entering just N. of Woodside Lodge.		30		5 lbs./lin. yd.	150

In front of Blarachorine 15 sq. yds. at 5 lbs./sq. yd. (75 lbs.) on rock exposure.

In front of Drumfronn 10 sq. yds. at 5 lbs./sq. yd. (50 lbs.) on rock exposure.

In front of Blair Atholl 4 sq. yds. at 5 lbs./sq. yd. (20 lbs.) Seaweed scarce, Gigartina at highest level.

Scattered and difficult to collect.

Scattered and difficult to collect, but clean.

(B.M. = O.S. Bench Mark.)

Variable, part spoiled by Enteromorpha and Porphyra.

On boulders: patchy.

Rocks almost vertical in southern half and Gigartina occurs in narrow zone just above the Laminaria. Only accessible by boat.

On stones where burn enters. Only accessible by boat.

TABLE III (contd.): CLYDE SEA-AREA
(a) LOCH LONG, LOCH GOIL AND THE GARELOCH

	Loch Goil (contd.)	4			2-3 lbs./lin. yd.		
Gigartina	N. of Blairlornmond slip to Lettermay burn.		300		2-3 lbs./lin. yd.	750	
do.	Round mouth of burn Eas a'Chruisgein.		100	20	9 " "	900	
do.	Lochgoilhead Bay, on N. side of river Goil.		25		5 " "	125	Present over the whole bay, in a zone up to 80 yds. with occasional rich patches.
do.	Leac Bhuidhe jetty to Woodlands S. jetty.		350	4-5	1 lb./lin. yd.	350	Richer near Woodlands.
Gigartina	Loch Long, from Loch Goil to Kilcreggan.	4			2 lbs./lin. yd.	40	
do.	S. of B.M. 10·2. N.E. of Meall Daraich.		20				
do.	Round burn S. of B.M. 19·1, $\frac{1}{4}$ mile S. of Portincaple Ferry Slip.		20		2 " "	40	
do.	Burn at Portincaple Ferry Slip.		75	Wide	3 " "	250	8-9 lbs./lin. yd. on edges of burn at Ferry Slip.
do.	Burn N. of Mark Farm.		25		5 " "	125	All of this section is accessible only by boat. There are numerous small areas of weed where fresh water enters.
do.	Burn about halfway between Torpedo range aiming point and last Admiralty mark.					50	
do.	Up to last T.M. (at 8,000 yds.).		250		1 lb./lin. yd.	250	
do.	Just N. of last T.M.		25	3-4	2 lbs./lin. yd.	50	
do.	Round Guanan burn.		40	3-4	3 " "	120	
do.	Burn about 250 yds. S. of T.M. at 6,000 yds. (2nd burn N. of Guanan burn).		50		1-2 " "	75	(T.M. = Torpedo range mark.)
Gigartina	From wall dividing bay S. of Coileassan for 150 yds.	4	150	14	2 lbs./lin. yd.	300	Tufts on stones. Richest to the south.
do.	In stony bay N. of rocky headland S. of Coileassan.		50		1 lb./lin. yd.	50	
do.	Round T.M., S. of Coileassan.		60	7	3 lbs./lin. yd.	180	
do.	Just N. of burn at houses halfway between Coileassan and Ardgartan.		100		1-2 " "	150	
do.	From south landing stage (jetty) to Croe water.		400		1 lb./lin. yd.	400	Variable, sometimes on mussel beds. Zone very wide near Croe Water.
Gigartina	W. side of loch head to River Loin.	4	300	Up to 70	12 lbs./lin. yd.	3,600	In small tufts on mussels. Scattered and troublesome to collect.
do.	From River Loin to Arrochar Pier.		500	Up to 10	2-3 " "	1,250	On mussels and small stones.

TABLE III (contd.): CLYDE SEA-AREA
(a) LOCH LONG, LOCH GOIL AND THE GARELOCH

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	<i>Loch Long, from Loch Goil to Kilcreggan</i> (contd.)	4					
do.	In bay at Arddarroch boathouse.		200	3-4	1-2 lbs./lin. yd.	300	Doubtful if worth collecting.
do.	From this bay to Portincaple jetty.		1,400		$\frac{1}{2}$ lb./lin. yd.	700	Patchy, doubtful if worth collecting.
do.	S. of boat slip S. of Portincaple, on rocks.		25		2 lbs./lin. yd.	50	
do.	Portincaple to burn N. of Port-an-Lochain.		3,700	1-5	$\frac{1}{2}$ lb./lin. yd.	1,950	Zone usually narrow, just above Laminaria. Occasional oil fouling at high levels.
do.	Round burn N. of Port-an-Lochain (B.M. 19.1).		150		3 lbs./lin. yd.	450	
do.	To half mile S. of Port-an-Lochain.		880		2 " "	1,760	From $\frac{1}{2}$ mile S. of Port-an-Lochain to rocks N. of Coulpport (B.M. 12.8) varies from 0-3 lbs./lin. yd., average $\frac{1}{2}$ or less; infested with Ulva. All this section accessible only by boat.
Gigartina	Just S. of burn beside Swiss Villa.	4	100 sq. yds.		1 lb./sq. yd.	100	
do.	Letter to Ardnahane.		300	5	1 lb./lin. yd.	300	Short and infested with Enteromorpha, Ulva and Porphyra.
do.	Rocks at Peaton Layo.		200		2 lbs./lin. yd.	400	Rather short, occasionally oily.
Gigartina	Rocks at Ardpeaton Lodge.	4				50	Badly infested with Porphyra.
do.	Ardpeaton Lodge to Spring at S. end of boulders, 50 yds. S. of road fork.		1,000		$\frac{1}{2}$ lb./lin. yd.	250	Tufts on stones. Hardly worth collecting.
do.	From 200 yds. N. of Auchengower boatslip, to boatslip.		200		1 " "	200	Very tarry.
do.	Port-nan-Each to Eilean Beg.		250		1 " "	250	Rhodymenia present in large quantities.
do.	Bay below Knockderry.		120		2 lbs./lin. yd.	240	Very oily and unpleasant.
Gigartina	Point below Knockderry Fort to Dowall burn.	4	700	3	1-2 lbs./lin. yd.	1,000	

TABLE III (contd.): CLYDE SEA-AREA
(a) LOCH LONG, LOCH GOIL AND THE GARELOCH

Gigartina	Loch Long, from Loch Goil to Kilcreggan (contd.) From 200 yds. N. of Shanton burn to Shanton burn.	4	200	20	2-3 lbs./lin. yd.	500	Rather short. Choked with Enteromorpha and covered with oil.
do.	Shanton burn to Cove Pier.		300	3-4	2 " "	600	Covered with oil. Growth of Porphyra and Enteromorpha.
do.	Two patches in bay near wooden jetty, near Craigmownie Castle.		20 sq. yds. 10 "		3 lbs./sq. yd. 3 " "	60 30	
do.	Next 200 yds. south.		200		2 lbs./lin. yd.	400	Scattered, hardly worth collecting.
do.	On headland below Hartfield.		50		5 " "	250	
do.	Round headland below U.P. Church.		250		4-5 " "	1,100	Clean.
do.	Patch on N. side of headland below Meikle-aiden Cottages.		40 sq. yds.		3 lbs./sq. yd.	120	
do.	S. part of headland below Meikleaiden Cottages.		50	10-15	16 lbs./lin. yd.	800	
do.	Rocky headland with trees S. of Meikleaiden Cottages.		250		2-3 " "	600	
do.	Flat bouldery stretch from rocky headland to 100 yds. W. of Cow and Calf.		500		2-3 " "	1,250	Very rich, but spoiled with oil and tar.
do.	Bay just W. of Cow and Calf.		100		4-5 " "	450	Oily.
do.	Round Cow and Calf headland.		150		3 " "	450	
do.	From Cow and Calf to 100 yds. W. of Pier.		400	Over 4	6 " "	2,400	
do.	From 100 yds. W. of Kilcreggan Pier, to Pier.		100	3-4	9 " "	900	Badly spoiled with oil. Shore slippery with Ulva.
Gigartina	Gareloch. From 30 yds. S.W. of slip to slip on N. side of Rhu Pt.	4	30	3-4	1-2 lbs./lin. yd.	45	
do.	In front of Letrault Lodge.		100		1-2 " "	150	
do.	Below Gully Bridge to Croy.		400	Up to 30	3-4 " "	1,400	Zone narrows and seaweed decreases from S. to N. 6-7 lbs./lin. yd. at bridge; not worth collecting at Croy.
do.	Croy N. Lodge to Stuckenduff.		250		2 " "	500	
do.	Ardgare to N. Lodge of Ardgare.		200	Wide	2-3 " "	500	A rich patch of 20 lbs. opposite Ardgare House.
do.	Chapel burn to Shandon Pier.		350		1-2 " "	500	
Gigartina	Shandon Bank to S. Lodge of Shandon Hydro.	4	400		1-2 lbs./lin. yd.	600	

TABLE III (contd.): CLYDE SEA-AREA
(c) KINTYRE PENINSULA: EAST COAST

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	KINTYRE PENINSULA: EAST COAST (surveyed June 1943).	5 & 6					
do.	From Tarbert old jetty 200 yds. S.E.		200	Up to 3	1 lb./lin. yd.	200	Opposite white bungalow.
do.	Rocky headland near road end.		100	2-3	2 lbs./lin. yd.	30	
do.	From just before disused pier for 100 yds. S.E.		70		$\frac{1}{2}$ lb./lin. yd.	200	
do.	Next headland.					35	
do.	Headland beyond breakwater just before sheer rocks.		100		1 " "	100	
do.	Mealдарoch Pt.		80	2	$1\frac{1}{2}$ lbs./lin. yd.	120	Accessible by boat.
do.	S. tip of Mealдарoch Pt.					20	
do.	Headland just S. of this.					40	
do.	From Croit Bagh to Skipness Pt.		5,000		$\frac{1}{2}$ lb./lin. yd.	2,500	Very variable. From 0 up to 2 lbs./lin. yd.
do.	On Skipness Point.					100	
do.	From Sgeir na Luining to where road bends away from shore.		900		$\frac{1}{2}$ " "	450	Slightly richer N. of road leading to Auchameanach.
Gigartina	From point S. of Claonaig Bay to beginning of headland Rudha na h'-airde Baine.	6	2,000		1 lb./lin. yd.	2,000	All easily collected.
do.	On headland Rudha na h'-airde Baine.		500	6-7	10 lbs./lin. yd.	5,000	
do.	From S. of headland to burn just N. of Sgeir Bheathaig.		1,000		5-6 " "	5,500	
do.	On Sgeir Bheathaig rock.					200	
do.	From Sgeir Bheathaig to Eascairt Pt.		700		1 lb./lin. yd.	700	
do.	From Eascairt Pt. to burn before Port Alasdair Ruaidh.		1,700		$\frac{1}{2}$ " "	850	
do.	Round headland at Sgeir Bhuidhe.		300		3 lbs./lin. yd.	900	
do.	Rocky spits between Sgeir Bhuidhe and Crossaig burn.					140	Four spits with 30-40 lbs. on each.
do.	From Port a'Mhiadair to Cour Bay.		2,300	2	1-2 " "	3,450	Difficult of access just S. of Rudha Riabhach.
do.	From S. end of Cour Bay, half way to Eilean Cour.		700	Narrow	$1\frac{1}{2}$ " "	1,000	
do.	From S. end of Eilean Cour for 100 yds.		100		1 lb./lin. yd.	100	
do.	Just N. of burn Allt a'Bheime.		50		1-2 lbs./lin. yd.	75	
do.	From there to Port Ban.		600	2-3	4 " "	2,400	

TABLE III (contd.): CLYDE SEA-AREA

(C) KINTYRE PENINSULA: EAST COAST

	Kintyre Peninsula: East Coast (contd.)	6	600	2-3	1½ lbs./lin. yd. 3 " ½ lb./lin. yd. 3 lbs./lin. yd. 3 " ½-1 lb./lin. yd.	900 2,100 100 450 60 300	Between Dearg Allt and Closeburn it is a little richer. On outer side. Accessible by boat. Richer in northern part.
Gigartina	From Port Ban to Close burn.		600				
do.	From Close burn to Port Sunadale.		700				
do.	Port Sunadale to Eilean Sunadale.		200				
do.	On Eilean Sunadale.		150				
do.	In Port a'Bhodaich.		20	3-4			
do.	S. of Sunadale.		400				
Gigartina	Rocks S. of Grogport to small burn just S. of cave.	6	1,700		1 lb./lin. yd.	1,700	Poorer for 100 yds. opposite Eilean Grianain.
do.	For 100 yds just S. of Cats burn (S. of Eilean Grianain Bay).		100		½ "	50	Last 30 yds. have 2 lbs./lin. yd.
do.	South of Eilean Grianain Bay.		600		½ "	340	
do.	Opposite brick shelter.					20	
do.	About 250 yds. N. of submarine telegraph hut.		100		1 "	100	
do.	Carradale Pier to Port Righ Bay.		1,200		½-1 "	900	Intermittent. Difficult to collect.
do.	South of Port Righ.		600		1 "	600	Best collected by boat.
do.	At south end of deer park.		100	1	1 "	100	Absent in bays.
do.	Round island at Carradale Point.		900	1	1 "	900	Very difficult of access.
do.	From rocks S. of Carradale Water to Dippen Bay.		600		½ "	450	Patchy.
do.	On Eilean Leathan.					600	Accessible only by boat.
do.	On rocks a few hundred yds. S. of Eilean Leathan.		250		6 lbs./lin. yd.	1,500	
do.	Round Pluck Point.		400	3-4	½ lb./lin. yd.	200	
Gigartina	From Port na Cuthaig to 200 yds. N. of Bunlarie burn.	6	700		1 lb./lin. yd.	700	
do.	From there to basalt dyke 500 yds. S. of Bunlarie burn.		700		5 lbs./lin. yd.	3,500	
do.	From basalt dyke to beginning of Ugadale Bay.		600		1½ "	900	
do.	Round Ugadale Point.		450		1 lb./lin. yd.	500	2 lbs./lin. yd. in the middle.
do.	S. of Allt Traigh-leacainn to first fort.		400		1 "	400	
do.	S. of Kildonald Point.		900		½ "	450	On rocks difficult of access.

TABLE III (contd.): CLYDE SEA-AREA
(c) KINTYRE PENINSULA: EAST COAST

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	<i>Kintyre Peninsula: East Coast (contd.)</i>	6					
do.	At southern tip of Black Bay.		350		1 lb./lin. yd.	60	
do.	Round Carrick Point.					350	
do.	Rocks at N. of Ardnacross Bay.					40	Only accessible at good spring tides.
do.	Rocks in middle of Ardnacross Bay.					500	" " " " " "
do.	On Smerby Rocks opposite tip of Yellow Rock.		150		3 lbs./lin. yd.	450	" " " " " "
do.	200 yds. each side of Stack.		400		1 lb./lin. yd.	400	
do.	Round double headland of fort, W. of Smerby burn.					20	
Gigartina	<i>Davarr Island:</i>	6					
do.	(i) Spit below most westerly cave.		50	2-3	1½ lbs./lin. yd.	70	
do.	(ii) From there for 1,000 yds. E. and N. round island.		1,000	Up to 10	1½ " "	1,500	
	(iii) Last 500 yds. of rocks on Davarr.		500	7-8	7 " "	3,500	Some parts are 8-10 lbs./lin. yd.
Gigartina	Point E. of Davarr House.	6				50	
do.	Rocks just N. of New Orleans.					150	
do.	Rocks S. of New Orleans to St. Ciaran's Cave.		1,200		½ lb./lin. yd.	600	
do.	Rocks S. of Achinchoan Bay to Achinchoan burn.		450		3 lbs./lin. yd.	1,350	
Gigartina	Achinchoan burn to Balnabraid Glen.	6	900	50	3 lbs./lin. yd.	2,700	On reefs only. Difficult of access except by boat.
do.	Balnabraid Glen to 50 yds. N. of first island.		900	50	4 " "	3,600	Quantity variable.
do.	From there to Ru Stafnish.		900	30	6 " "	5,400	Thickest on outer reefs. Difficult of access.
do.	Ru Stafnish to beginning of Doon amphitheatre.		2,800	Up to 100	10 " "	28,000	On reefs and in lagoons. Difficult to collect except by boat. In parts much richer.
do.	From there to Glen Hervie Ford.		900		4 " "	3,600	Zone narrower. Reefs diminish in area.
Gigartina	Glen Hervie Ford to S. end of the Castles.	6	1,000		½ lb./lin. yd.	500	On islands only and these are offshore; very difficult to collect.
do.	On Rudha McShannuich.		200		2-3 lbs./lin yd.	500	
do.	Rocks in Brunerican Bay.		400	20	1-1½ " "	500	
do.	Dunaverty.					150	Rich on rocks near jetty.
do.	Kiel Point.		400		½ lb./lin yd.	200	
							TOTAL WEIGHT FOR THE EAST COAST OF THE KINTYRE PENINSULA IS 43·8 TONS.

TABLE III (contd.): CLYDE SEA-AREA

(d) AYRSHIRE AND WIGTOWNSHIRE: (i) WEMYSS BAY TO ARDROSSAN

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT			NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.
Gigartina	AYRSHIRE AND WIGTOWNSHIRE: (i) WEMYSS BAY TO ARDROSSAN (<i>surveyed June and July 1943</i>).	7				
do.	From N. end of Wemyss Plantation for 300 yds. to S.		300	15	$\frac{1}{2}$ -1 lb./lin. yd.	200 High levels spoiled by mussels.
do.	From 100 yds. before S. end of plantation, to 100 yds. before Castle Wemyss Pier.		300	5	2 lbs./lin yd.	600
do.	From there to Castle Wemyss Pier.		100	2	$\frac{1}{2}$ -1 lb./lin. yd.	70
do.	From S. end to Meigle Bay to S. lodge entrance of Ashcraig.		450		1 " "	450 Sometimes on rocks, sometimes on boulders. Coast from Ashcraig to Blue Stones, absent or not worth collecting.
Gigartina	On Blue Stones.	7				
do.	From 200 yds. S. of Blue Stones to North- bank.		700		2-3 lbs./lin. yd.	20 1,750 Quantity variable; sometimes as rich as 5 lbs./lin. yd.
do.	Northbank Farm to Portencross Pier.		500		4 " "	2,000 On rock tips.
do.	East end of Farland Head.					60
do.	On Bell Stane.		600	5	1 $\frac{1}{2}$ " "	900 Richer to N., particularly on rock tips.
do.	Seamill Burn to North Inch.		900		2 " "	1,800 Richer on first 200 yds., 2-3 lbs./lin. yd.
do.	Point between North and South Inch.					80
do.	Rock exposure North of Gourock Burn.		900	Up to 50	2 " "	1,800 Most on lowest 5 yds. of zone. Also present on rocks off shore.
do.	Three rock spits below Ann's Lodge: North Spit Middle Spit South Spit		20 50 50	5-10 5-10	2 " " 2 " " 5 " "	40 100 250
do.	Rock exposure opposite Scart Rock.		20	10	2 " "	40
do.	Rock exposure in front of Crawford's Lodge.		100	5-7	5 " "	500
do.	Along Long Craigs.		300		$\frac{1}{2}$ lb./lin. yd.	150 Scattered tufts among boulders. Also present on rocks off shore. TOTAL WEIGHT FOR WEMYSS BAY TO ARDROSSAN IS 4.85 TONS.

TABLE III (contd.): CLYDE SEA-AREA
(d) AYRSHIRE AND WIGTOWNSHIRE: (ii) WRIGHT'S ISLAND TO BURROW HEAD

ALGA	LOCALITY	MAP	The weight of alga in this area was estimated by a different method from the foregoing and subsequent areas : only the total weights are given.	TOTAL WT. IN LBS.	NOTES
Gigartina	AYRSHIRE AND WIGTOWNSHIRE : (ii) WRIGHT'S ISLAND TO BURROW HEAD (surveyed May and June 1943).	8		3,000	Forms a continuous belt between <i>F. serratus</i> and <i>Laminaria</i> . Sometimes associated with <i>Laurencia</i> .
do.	Shingle from Wright's Is. to Girvan Mains.			10-20	Spoiled by mussels.
do.	N. of Girvan Harbour.			780	Only exposed at very low tides.
	S. of Girvan Harbour and Pier.				
Gigartina	Girvan Bay.	8		10-20	On boulders in sand.
do.	Cow and Horse Rock.			50	
do.	Craigskelly.			40-50	Mostly on seaward side of rocks.
do.	Woodland Bay.			10	" " " "
Gigartina and Chondrus	Black Neuk.	8		140	Under <i>F. serratus</i> .
Gigartina	Rocks S. of Port Cardloch.			140	Similar to above.
do.	N. of Ardwell Bay.			112	At end of shingle 'peninsula'.
do.	Kennedy's Pass Bay.			400	On red sandstone among <i>F. serratus</i> .
Gigartina and Chondrus	Pinbain Bridge to Lendalfoot.			1,000	On boulders near low water mark.
Gigartina	Lendalfoot, S. of bridge.	8		500	On shingle.
do.	Carleton Bay.			50	
do.	Burnfoot.			100-200	
do.	Port Vad.			50	
do.	Bennane Head to Drummore shore.			500	With <i>Laurencia</i> and <i>F. serratus</i> . Richer to N.
do.	S. of road to Colmonell.			200-250	Occasional mussels.
do.	Opposite Colmonell Road to Ballantrae.			280	On rocks at L.W.O.S.T.
Gigartina and Chondrus	N. of Downan Pt.			1,000-1,500	In pools, with a small amount of <i>Chondrus</i> .
Gigartina	Downan Pt. to Dove Cove.			1,750-2,250	Some infested with mussels.
do.	N. of Currarie Port.			350-400	On boulders and on a platform below cliff.
do.	S. of Currarie Port.			100-200	

TABLE III (contd.): CLYDE SEA-AREA

(d) Ayrshire and Wigtownshire: (ii) Wright's Island to Burrow Head

			8	The weight of alga in this area was estimated by a different method from the foregoing and subsequent areas: only the total weights are given.		
Gigartina	<i>Ayrshire and Wigtownshire etc. (contd.)</i>					
do.	Knock Bay, N. of burn.				200	Mixed with Porphyra.
do.	Killantringan Bay.				50	With Rhodymenia.
do.	N. of Black Head Lighthouse.				50	
do.	Port Kale.				2,000-3,000	On boulders with Fucus and Laurencia.
do.	Port Mona.				500	
do.	Morroch Bay.				1,000-1,500	
do.	S. of Port of Spittal Bay.				250-300	Dense, associated with Laminaria and Himanthalia.
Gigartina and Chondrus	Drumbreddan Bay.				1,000	In pools, with a small amount of Chondrus.
Gigartina	Port Lochan.				1,500	On rocks at sides of bay.
do.	Port Gill.				1,000	
Gigartina and Chondrus	N. of Port Logan Bay.				1,000	
Gigartina	Clanyard Bay.				1,000	On boulders with Himanthalia.
do.	Portencorkrie.				1,500	Forms a distinct belt. A little Chondrus in pools.
Gigartina and Chondrus	West Tarbet.				2,000	On boulders: 30% Chondrus.
do.	Portankill.				6,000	TOTAL WEIGHT FOR WRIGHT'S ISLAND TO BURROW HEAD IS 14.5 TONS.

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (i) BUTE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	BUTE (surveyed June and July 1942). Between Rothesay Pier and Craigmore Pier.	9					Present in small quantities, but not worth collecting.
Gigartina	Rocks opposite Albany Rd.	9	20 sq. yds.		8 lbs./sq. yd.	160	
do.	Rock exposure a little E. of above.		10 sq. yds.		3 " "	30	
do.	On Bogany Pt.		150		1½ lbs./lin. yd.	225	Troublesome to collect.
do.	Round sewer house.		200		1½ " "	300	
do.	Stone jetty at 55° 50' 30" N.		36 sq. yds.		2 lbs./sq. yd.	70	On jetty. Overgrown with lavers.
do.	From here to boathouse, 50 yds. S. of shelter on shore.		250	2	3 lbs./lin. yd.	750	Mussels present and weed very badly covered with laver.
do.	Rock exposures: (i) S. of boathouse		10	20	17 " "	170	
do.	(ii) 50 yds. S. of shelter on shore		10	20	17 " "	170	
Gigartina and Chondrus	From here to Millburn Bay.		700	3-12	7 " "	4,900	On boulders and occasional rocky faces. Chondrus at high levels.
do.	S. headland of Millburn Bay.		25	3	12 " "	300	Clean.
do.	Headland to Ascog Bay.		500		7 " "	3,500	Mussels at high levels.
Gigartina	S. side of Ascog Bay.	9	10 sq. yds.		2 lbs./sq. yd.	20	Very difficult to collect. N. face only.
do.	On Ascog Rock.		330	6	8 lbs./lin. yd.	2,640	Badly infested with small mussels, except on vertical faces. Not recommended for harvesting.
do.	From breakwater to Blair Lodge boatslip.		750	Up to 12	7 " "	5,200	Infested with mussels except at low levels. Where boulders begin 100 yds. N. of sewage pipe mussels die out, but Ulva present. Rich (up to 15 lbs./lin. yd.) where Ulva is absent.
do.	Blair Lodge boatslip to 100 yds. N. of Black burn.		500		3-4 " "	1,700	Infested by mussels and laver. Harvestable.
do.	Rocks from The Hermitage to Kerrycroy Bay.		100		4 " "	400	
do.	On rocky ridge between Kerrycroy and R.C. Chapel.		70	5	7 " "	490	
do.	Bay S. of R.C. Chapel.		100	3	30 " "	3,000	
do.	Round Scoulag Pt.		600		4 " "	2,400	Richness variable.
do.	Scoulag Pt. to boathouse.						

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (i) BUTE

	<i>Bute</i> (contd.)	9	20 sq. yds. 100	4-5	5 lbs./sq. yd. 15 lbs./lin. yd.	100 1,500
Gigartina	Rocky ridge halfway to Kerrylamont Bay.					
do.	Headland S. of Bruchag Pt.					
do.	From there to Kilchattan Bay.					
do.	Kilchattan Bay from stone quay to pier.		400	2-10	4 " "	1,600
do.	Kilchattan Pier to gate to S.		350		5 " "	1,700
do.	Isolated rocks near gate.		10-15 sq. yds.		5 lbs./sq. yd.	60
do.	Up to first stony bay S. of gate.		50		5 lbs./lin. yd.	250
do.	Isolated point S. of stony bay.		25		4 " "	100
do.	From here to White Port.		200		6 " "	1,200
do.	White Port to S. cave.					Not worth collecting.
Gigartina	S. cave to Hawk's Nib.	9	250	10	5 lbs./lin. yd.	1,200
do.	Below Hawk's Nib.		15 sq yds.		8 lbs./sq. yd.	120
do.	For 200 yds. S. of Hawk's Nib.		200		6 lbs./lin. yd.	1,200
do.	From here to lighthouse.					Upper part infested with mussels, but not included in estimate.
do.	Inlets: (i) 25 yds N. of lighthouse (ii) 100 yds. N. of lighthouse (iii) just W. of lighthouse		50 sq. yds. 30 sq. yds. 10 sq. yds.		8 lbs./sq. yd. 8 " " 8 " "	400 240 80
do.	N.E. side of Glencallum Bay.		250	5	6 lbs./lin. yd.	1,500
do.	Boyd's Port.		50	12	1 lb./lin. yd.	50
do.	On N. side of point (Roinn Clumpach).		20 sq. yds.		6 lbs./sq. yd.	180
do.	Small bays on W. side of point.		100		4 lbs./lin. yd.	400
do.	E. side of Port na Caillich.		300		5 " "	1,500
do.	In Port na Caillich.		50		1 lb./lin. yd.	50
do.	E. side of Port Luchdach.		175		9 lbs./lin. yd.	1,600
do.	Bay between Port Luchdach and Port Leithne, E. side.		150		9 " "	1,350
do.	W. side of Bay.		150		4 " "	600
do.	Port Leithne and point between Port Uisg and Port Leithne.					Present in some quantity, but no estimate made.

Always present in fair quantity, but too badly infested with mussels to be worth collecting.

Moderately clean and free from mussels.

Poor for 50 yds. on boulders. Mussels at high levels.

Very steep, parts almost inaccessible.

Not worth collecting.

Upper part infested with mussels, but not included in estimate.

Present only in sheltered coves. Rocks very steep and inaccessible.

In boulder zone.

Absent on W. side of west bay. Mussel-infested but harvestable.

A few small mussels among the weed.

Difficult to collect. Absent on W. side.

None on W. side.

Present in some quantity, but no estimate made.

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (i) BUTE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	<i>Bute</i> (contd.) Point W. of Port Uisg to Garroch Hd.	9	500	Up to 5	2-8 lbs./lin. yd.	2,500	Very variable, and mussels in some places. First two small points W. of Port Uisg are worth collecting, the next 5 are not, the others only on tips and west sides.
Gigartina	Garroch Head to Uamh Capuill.	9	1,000		1½ lbs./lin. yd.	1,500	Richness variable, increasing from Garroch Head. All worth collecting.
do.	Uamh Capuill to Garrochty Harbour (Cradh Rudha).		1,000		5 " "	5,000	
Gigartina	Patch N. of Garrochty Harbour.	9	200 sq. yds.		5 lbs./sq. yd.	1,000	None in harbour inlet.
do.	N. side of Garrochty Harbour, to Port Dornach.		500	2	8 lbs./lin. yd.	4,000	
do.	Port Dornach to S. side of Dunagoil Bay.		300	3	7 lbs./lin. yd.	2,100	Occasional mussels.
do.	N. side of Dunagoil Bay and Dunagoil Bay itself.						Sparse, hardly worth collecting.
do.	N. side of basalt sill on S. side of Lubas Bay.		10		3½ " "	35	
do.	On S. side of Dunstrone basalt sill.		75		7 " "	525	
do.	Below Dunstrone Fort to point S. of Lubas Port.		100	6	6 " "	600	
do.	Lubas Port to S. side of Stravanan Bay (west of putting green).		650	6	12 " "	7,800	Basalt boulders and dykes not colonised. Particularly rich (18 lbs./lin. yd.) on the ledges at 55°45' N. Rocks N. of putting green (not included) spoiled by mussels and oil.
Gigartina	100 yds. N. of Stravanan Bay, to 50 yds. S. of ledges S. of Gallachan Bay.	9	700	4-12	16 lbs./lin. yd.	11,200	
do.	Ledges S. of Gallachan Bay.		50		6 " "	300	
do.	Rocky ledges just N. of Gallachan Bay.		50 sq. yds.		8 lbs./sq. yd.	400	
do.	S. of rock exposure shown on 6" O.S. map just S. of Scalpsie Bay.		150	Up to 6	24 lbs./lin. yd.	3,600	South of this, Gigartina is replaced by Laurencia except in one small area.
do.	Rocks S. of Scalpsie Bay.		300	2-3	6 " "	1,800	Occurs 2 yds. seaward of Ascophyllum zone, among <i>F. serratus</i> .

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (i) BUTE

	<i>Bute</i> (contd.)	9	25	5	1 ½ lbs./lin. yd.	40
Gigartina	Ardscalpsie, S. point.		25	5	1 ½ lbs./lin. yd.	40
Gigartina and Chondrus	Between Port Loddan and sandy bay to S. (S. of Mecknoch Farm), on N. side and tip.		80	3-4	4 " "	300
						Chondrus present in small quantities.
		9				None worth collecting between Port Loddan and Greenan burn. Gigartina continues in very small quantities right round the N. end to Ardmaleish Pt.
Gigartina	Ardmaleish Pt. to boatslip.		150	2	½ lb./lin. yd.	40
Gigartina and Chondrus	Rocky ridge S. of Ardmaleish boatslip.		20 sq. yds.			Not worth collecting.
Gigartina	In front of church (Stella Maris) near Ardbeg Pt.		40	10	3 ½ lbs./lin. yd.	30
do.	Rocky ridge E. of Ardbeg Pt.		150		3 " "	Chondrus present in very small quantities.
do.	Tip of Ardbeg Pt.		20		3 " "	Growing among dense <i>F. serratus</i> .
						Some richer patches, a few sq. yds. in extent. Difficult to collect.
						TOTAL WEIGHT FOR BUTE IS 38.75 TONS.

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (ii) INCHMARNOCK

[illegible]

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (iii) GREAT CUMBRAE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	GREAT CUMBRAE (surveyed June and September 1942).	10					
do.	Old Pier to Bessy's Port.		140	Narrow	1 lb./lin. yd.	140	Richer patch where sewer enters.
do.	Bessy's Port to Bathing Slip.		180	Variable	2 lbs./lin. yd.	360	In the inlet, rich only on boulders.
do.	Bathing Slip to Foul Port.		70		6 " "	420	Not worth collecting.
do.	Foul Port.						
Gigartina	Small bouldery bay beyond Foul Port, up to sewer opposite 7th house from S. end of bay.	10	70		5 lbs./lin. yd.	350	
do.	Sewer, S. for 100 yds.		100		10 " "	1,000	
do.	Next 100 yds.		100		2 " "	200	
do.	100 yds. up to boat slip.		100		12 " "	1,200	About 6 lbs./sq. yd. of thickly-growing Gigartina.
Gigartina	100 yds. S. of boatslip.	10	100		12 lbs./lin. yd.	1,200	
do.	Bouldery bay.		10		6 " "	60	
do.	On steep rocky face.		70		12 " "	840	
do.	Up to jetty.		70		7 " "	500	Boulders; poorer quality of weed.
do.	Point beyond jetty, across strait.		70		8 " "	560	Richness varies up to 12 lbs./lin. yd.
do.	Bouldery bay.		50		4 " "	200	
do.	Rocky ridges.		50		8 " "	400	Two rocky ridges covered with Gigartina.
do.	100 yds. to Portachur Pt.		100	Up to 20	8 " "	800	
do.	From there to Doughend Hole.		900	Very wide	1 lb./lin. yd.	900	Varies from 0.5 lbs./lin. yd. Hardly worth collecting.
Gigartina	Doughend Hole, to half way to edge of cliff.	10	150	Wide	2½ lbs./lin. yd.	350	Mostly poor short plants, except for occasional rich boulders.
do.	Up to inlet S. of quarry.		420		4 " "	1,700	Still mostly short.
Gigartina	Quarry to Sheriff's Port.	10	800	3-15	9 lbs./lin. yd.	7,000	
do.	Boulders N. of Sheriff's Port.		70	Wide	4½ " "	300	
Gigartina	N. for 300 yds.	10	300		12½ lbs./lin. yd.	3,750	4.5 sq. yds. of Gigartina, averaging 3 lbs./sq. yd., for each yard of shore.
do.	Up to Clate Rock.		200		5 " "	1,000	2-3 sq. yds. Gigartina per yd. of shore: 1-3 lbs./sq. yd.

TABLE III (contd.): CLYDE SEA-AREA
(e) ISLANDS: (iii) GREAT CUMBRAE

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	Great Cumbrae (contd.) Clate Rock to Fintray Bay.	10	750		2 lbs. /lin. yd.	1,500	Mostly short and stunted. In places mussel-infested and overgrown with Ulva.
do.	Fintray Bay.		200		2 " "	400	None.
do.	Fintray Bay to Bell Bay.		100		2 " "	200	From where rocks begin beyond end of wood, very poor at first, improving.
do.	Rocks on N. of Bell Bay, for 100 yds. From 50 yds. S. of Little Skate Bay, to Little Skate Bay.		50		1 lb. /lin. yd.	50	Not worth collecting for 150 yds. before this.
Gigartina	N. side of Little Skate Bay, to Skate Bay.	10	550		5½ lbs. /lin. yd.	3,000	Richness very variable : 2-12 lbs./sq. yd. Poor in Skate Bay itself.
do.	From 200 yds. N. of Skate Bay to Eerie Port.		420		12 " "	5,000	2 sq. yds. per yd. of shore. Occasional mussels. Better at lower levels.
Gigartina	Eerie Port for 100 yds. N.	10	100	Wide	5 lbs. /lin. yd.	500	Good at low levels only.
do.	There to Stinking Bay.		200	5-40	4 " "	800	1 sq. yd. per yd. of shore. Best on rock faces. Some on boulders. None in Stinking Bay. High levels spoiled by mussels.
do.	Stinking Bay to Wine Bay.		70		5 " "	350	Best at S. end. None in Wine Bay.
do.	Wine Bay to White Bay.		550	Up to 40	4 " "	2,200	Mussel-infested at high levels. Good at low levels. None in White Bay.
Gigartina	White Bay to Monument.	10	420		8 lbs. /lin. yd.	3,400	Varies from 1-6 sq. yds./yd. of shore. Mussels on upper levels, 100 yds. before Monument.
Gigartina	Monument to Lady's Bay.	10	350	2-4	6 lbs. /lin. yd.	2,100	1½ sq. yds./yd. of shore at 4 lbs./sq. yd.
do.	Lady's Bay to Holm Bay.		340	10	2½ " "	850	Rich on small boulders.
do.	Point S. of Holm Bay.		20	1-2	6 " "	120	
do.	Point N. of boat jetty (the boathouse on 6" O.S. map).		30	1-2	6 " "	180	
do.	At rocky point, 50 yds. S. of jetty.		20	2	1½ " "	30	
Gigartina	Balloch Bay, S. end.	10	30	5	3 lbs. /lin. yd.	90	On boulders.

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (v) ARRAN

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	ARRAN (surveyed May 1943).	11					
do.	Fallen Rocks for 75 yds. N.		75		1½ lbs./lin. yd.	110	Survey starts 300 yds. N. of Fallen Rocks.
do.	Fallen Rocks.					50	Inaccessible for harvesting.
do.	From end of wood to 600 yds. N. of N. Sannox burn, where rocks reach low tide level.		1,000		1-1½ "	1,250	
do.	400 yds. N. of N. Sannox burn, up to burn itself.		400		1½-3 "	800	2½ lbs./yd. from where rocks come down to shore, up to burn.
do.	Pebbles between two mouths of burn.		20	10	2 "	40	
do.	From N. Sannox burn to 100 yds. N. of Sannox burn.		1,200	5-10	1 lb./lin. yd.	1,200	On boulders mostly.
do.	100 yds. N. of Sannox burn, to Sannox burn.		100	5-10	2 lbs./lin. yd.	200	On rock exposure.
do.	Corrie harbour.					50	On red sandstone blocks.
do.	Round Corrie burn.		440		½ lb./lin. yd.	220	
do.	Just S. of Birchpoint.		350		½-1 "	250	
do.	At Merkland Point.					20	
do.	From 100 yds. W. of sandy bay to Brodick Pier.		600		2 lbs./lin. yd.	1,200	Spoiled by oil.
Gigartina	Brodick Pier for 1 mile E.	11	1,760	5-6	1 lb./lin. yd.	1,760	2-3 lbs./lin. yd. at beginning of stretch, then from 400-700 yds. S. of Pier 2 lbs./lin. yd. and richer on boulders to S.
do.	Towards Corrygills Pt.		400		½ "	200	Hardly worth collecting.
do.	On Corrygills Pt.		250		1-2 lbs./lin. yd.	375	
do.	From burn S. of Corrygills Pt. southwards.		50	10	3-4 "	175	
do.	On flat stones for 30-40 yds. S.		35	7-8	6 "	210	
do.	From there to Clauchlands Pt.		2,200		¾ lb./lin. yd.	1,650	Variable quantities, up to 2 lbs./lin. yd. in places.
do.	Clauchlands Pt.		100		3-4 lbs./lin. yd.	350	
do.	Clauchlands Pt. to Coastguard Station E. of burn.		600		2 "	1,200	

TABLE III (contd.): CLYDE SEA-AREA

(e) ISLANDS: (v) ARRAN

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	Arran (contd.)	11				20	
do.	On tip of Kingscross Pt.						
do.	Kingscross Pt. to end of rock exposure N. of Whiting Bay.		1,030		3 lbs./lin. yd.	3,100	Varies from $\frac{1}{2}$ -4 lbs./lin. yd.
do.	Just E. of Church at Knockenkelly.		50		1 lb./lin. yd.	50	
do.	Rock exposures N. of Whiting Bay Pier.					20	
Gigartina	Stone jetty S. of Pier and boulders S. of this.	11				20	
do.	On shingle spits at Glenashdale burn.		150		1 lb./lin. yd.	150	
do.	From rocky exposure S. of Glenashdale burn, to 2nd farm N. of Largybeg Pt.		600	3-4	2-3 lbs./lin. yd.	1,500	Not so good at beginning of this stretch.
do.	Rocky ledge forming small head $\frac{1}{2}$ mile N. of Largybeg.		20		1 $\frac{1}{2}$ " "	30	
do.	200 yds. S. of this.		200		1 lb./lin. yd.	200	
do.	From 650-250 yds. N. of Largybeg.		400		1 $\frac{1}{2}$ -2 lbs./lin. yd.	700	
Gigartina	Round Largybeg Point.	11				400	Variable, maximum 2-3 lbs./lin. yd.
do.	Dippin Point.		100		2 lbs./lin. yd.	200	
do.	Round Dippin Head up to bouldery bay.		150		3-4 " "	525	
do.	Boulders, to 200 yds. before burn.		400		1 $\frac{1}{2}$ " "	600	
do.	Long rocky spits.						A few lbs. on each. Hardly worth collecting and difficult of access.
Gigartina and Chondrus	Levenacoroch burn to Black Cave.	11	2,000	Up to 50	1-2 lbs./lin. yd.	3,000	Partly Chondrus in Corallina lagoons. Always under water and very difficult of access. Gigartina scarce. Much Laurencia present on outer rocks.
Gigartina	Black Cave to 100 yds. east.		100	9	18 " "	1,800	Very difficult of access.
do.	Last spit before Chapel near Eilean Mairi.					35	
do.	First dyke past Torrylin Water.					100	Next dyke almost worth collecting.
do.	Ledge parallel to sea 50 yds. W. of Sliderry Waterfoot.					20	

TABLE III (contd.): CLYDE SEA-AREA

(c) ISLANDS: (v) ARRAN

	Arran (contd.)	11		Wide			
Gigartina	On sides of small sandy bay 10 yds. wide in front of 'Montana' Hotel in Blackwater Foot.	11	70		20		
do.	20 yds. S. to 50 yds. N. of Blackwater burn.		150		50		
do.	From where road leaves shore, for 150 yds. N.				300		
do.	On rocky point just N. of this.				75		
Gigartina	Rocks at Drumadoon Pt. to the Doon.	11	740	5	740	1 lb./lin. yd.	Laurencia and Gigartina equally abundant. Boulder area in front of Doon has Laurencia only.
do.	Red sandstone ridges N. of the Doon.		500	10	500	1 " "	Whole length of spit.
do.	On dyke at Cleiteadh nan Sgarbh.		300		600	2 lbs./lin. yd.	
do.	From boulders below King's Cave, to basalt sill N. of caves.		500		3,000	6 " "	
do.	From N. of sill to $\frac{1}{4}$ way to Leacan Ruadha.		300		1,800	6 " "	Ends where red sandstone ends.
do.	From there to 200 yds. short of cottage at Leacan Ruadha.		100		100	1 lb./lin. yd.	
do.	200 yds. S. of cottage, to cottage.		200		400	2 lbs./lin. yd.	Basalt dykes have none.
do.	String Road to Chapel (site of).		880	10	5,720	6-7 " "	Rich rocky exposure of about 70 yds. with 14 lbs./lin. yd. at about the middle of this stretch.
do.	From Chapel (site of) to Dougrie burn.		1,320		1,320	1 lb./lin. yd.	
do.	Rocky ledges below Cnoc Donn.		20		50	2-3 lbs./lin. yd.	At extreme low water.
do.	Spit $\frac{1}{4}$ mile S. of Imachar Farm.		30		60	2 " "	
do.	Slaty rock W. of little creek near Imachar Pt.				60		
do.	From beyond first burn where high cliff ends, to halfway to Whitefarland cottage.		750	4	2,250	3 " "	Some mussels. Second half of this stretch much easier of access than first.
do.	From here to where boulders begin.		300		300	1 lb./lin. yd.	
TOTAL WEIGHT FOR ARRAN IS 18.35 TONS.							

TABLE IV (contd.): MAINLAND COAST AND INSHORE ISLANDS

Gigartina	} Loch Sween to Oban (contd.) E. side of strait, between N. end of Eilean Traighe and mainland. S. side of Carsaig Bay.	5	350 400		$\frac{1}{2}$ lb./lin. yd. 1 " "	170 400	Gigartina above and Chondrus lower down.
Gigartina			700 500 2,600		$\frac{1}{2}$ " " $\frac{1}{4}$ " " $\frac{1}{4}$ - $\frac{1}{2}$ " "	350 120 1,000	Some patches 1-2 lbs./lin. yd. This probably continues most of the way to Ardnoe Point.
do. do.							
Gigartina	From Rudha na h-Airde Droighniche to boulders halfway up opposite Carsaig Island.						
do.	N. end of Leth Sgeir for 500 yds. N.						
do.	On all rocks except in sheltered bays up to Dounie.						
Gigartina	South of boulders at Port nan Athlaich, Craignish.	5	200		$\frac{1}{2}$ lb./lin. yd.	100	There is a prominent dyke at about the middle of the stretch.
do.	N. of boulders at Port nan Athlaich to Pier.		500		$\frac{1}{2}$ " "	250	
do.	N. of Pier for 200 yds.		200		$\frac{1}{4}$ " "	50	
do.	Between Eilean Ona and Bagh Ban.		700		$\frac{1}{2}$ -1 " "	500	
do.	Just W. of Fort.		100		5 lbs./lin. yd.	500	
do.	Between Fort and Bagh Ban.		100		2-3 " "	250	
Gigartina	At Sgeir a Chleirich, Seil Sound.	5	100		2 lbs./lin. yd.	200	
do.	On headland below fort, E. of Minard Point.		50		1 lb./lin. yd.	50	
do.	From Minard Point, N. (Sound of Kerrera).		300		3 lbs./lin. yd.	900	Good rock to S. of this stretch, with 10-20 lbs.
do.	From bay N. of Minard Pt., to entrance of Port na Traigh-linne.		1,600		$\frac{1}{2}$ lb./lin. yd.	800	Richer on flat rocks, little on vertical rocks. Present at a very low level.
do.	Round point with ruins of castle.		300		$\frac{1}{2}$ -1 " "	200	
do.	Rocks on S. side of Port Lathaich.		50		1 " "	50	
do.	N. side of Port Lathaich.		300	3	3 lbs./lin. yd.	900	
Gigartina	Island of Luìng.	5	2,100		$\frac{1}{2}$ lb./lin. yd.	1,050	Quality poor.
do.	Rudh Ard Luìng to bay S. of Camas nan Gall.		150		1 " "	150	
do.	Projecting headland N. of Camas nan Gall.		500		$\frac{1}{2}$ " "	250	
do.	From here to Pier, S. of Rudha Cuil.		100		1 " "	100	
do.	Below Cobblers of Lorn.		1,800		$\frac{1}{2}$ " "	900	
do.	Cobblers of Lorn to where offshore islands begin.		200		$\frac{1}{4}$ " "	50	Richer to south.
do.	In front and to S. of Cullipool village.		750		$\frac{1}{4}$ - $\frac{1}{2}$ " "	300	Poorer where rocks are steep.
do.	Between Cullipool and Stac na Morain.		700		$\frac{1}{4}$ - $\frac{1}{2}$ " "	250	
do.	Stac na Morain to Cuan Point.		700		1 $\frac{1}{2}$ lbs./lin. yd.	1,050	Richest on points of rock.
do.	Cuan Point to Cuan Ferry.						

TABLE IV (contd.): MAINLAND COAST AND INSHORE ISLANDS

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	<i>Island of Seil.</i> Rocks W. of Cuan Ferry up to harbour at Easdale, Seil.	5	3,700		$\frac{1}{2}$ -1 lb./lin. yd.	2,800	Islands and flat rocks near Meall Donn have 1-2 lbs./lin. yd. but they are difficult of access.
do.	From beacon N. of Pier to Rudha Mhic Mharcuis.		500		1 " "	500	
do.	Rudha Lagain Aillidh to Rudha Garbh Airde.		900		$\frac{1}{2}$ -1 " "	650	Poorer towards north.
do.	On point, S. of Eilean Buidhe.					50	
Gigartina	<i>Island of Easdale.</i> Rock at east pt. of Camas Mor.	5				50	
do.	Rocky points and west side of Camas Mor.		800		1-3 lbs./lin. yd.	1,600	
do.	Rocks in bouldery bay on N. side.					20	TOTAL WEIGHT FOR MULL OF KINTYRE TO OBAN, INCLUDING ISLANDS OF LUING, SEIL AND EASDALE, IS 11.1 TONS.

TABLE V: OFFSHORE ISLANDS

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT				NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	TOTAL WT. IN LBS.	
Gigartina	ISLAY (surveyed July 1943). Rudh' a 'Mhail to Gleann Dubh burn.	12	1,760		$\frac{1}{2}$ lb./lin. yd.	440	Richer at beginning of this stretch—up to 1 lb./lin. yd. on rocky tips near lighthouse.
do.	Steep faces south of this.		250		$\frac{1}{2}$ -1 " "	200	
Gigartina and Chondrus	On rocks at Aonan nan Van.		50		2 lbs./lin. yd.	100	
Gigartina	From Aonan nan Van to Carraigian Daimh.		300		$\frac{1}{2}$ lb./lin. yd.	70	
do.	On Rudha Bhaohlaig.		150		$\frac{1}{2}$ " "	40	

TABLE V (contd.): OFFSHORE ISLANDS

Gigartina do.	Islay (contd.) On N. side of Rudh' a Chladaich. Rocks offshore, S. of Carraig an Rath.	12	200			$\frac{1}{4}$ lb./lin. yd.	50 10	
Gigartina	On the islands offshore on Loch an t-Sailein and round Ard Imersay.	12					1-2 tons	Can be reached by boat only. Little present on the shore itself.
Gigartina do.	In Port an Tobair, Laggan headland. S. of Port Mor, to Rudha Buidhe.	12	1,000	Up to 4		$\frac{1}{4}$ lb./lin. yd.	20 500	Amount variable. Richer in northern half.
Gigartina do.	$\frac{1}{4}$ mile S. of Bruichladdich Pier, southward.	12	500			$\frac{1}{4}$ - $\frac{1}{2}$ lb./lin. yd.	300	
do.	In Port Charlotte Bay.		40			1-2 lbs./lin. yd.	30 60	
do.	Rocks S. of Port Charlotte.					$\frac{1}{4}$ lb./lin. yd.	1,250	Also present on rocks off coast. Much of it could only be collected by boat.
do.	50 yds. S. of Port Charlotte, to opposite Eilean Dubh.		2,500			$\frac{1}{4}$ lb./lin. yd.		
Gigartina and Chondrus	In Port Wemyss.		250			$\frac{1}{4}$ " "	120	
do.	In Portnahaven.		500			$\frac{1}{4}$ " "	250	
do.	On Orsay.		880		$\frac{1}{4}$ yd.	$\frac{1}{4}$ " "	440	Only N. side examined.
Gigartina	On Eilean Mhic Coinnich.		880			$\frac{1}{4}$ " "	440	Present also on offshore rocks. Only N. side examined.
do.	In Port Froige.						50	Poor and hardly worth collecting.
do.	In An Gleann.						30	In clefts in the rock.
do.	Between Eilean Liath and Kilchiaran Bay.						300	In sheltered creeks.
do.	S.E. corner of Kilchiaran Bay.						20	
do.	N. side of Kilchiaran Bay.		100			$\frac{1}{4}$ lb./lin. yd.	25	
do.	Deep bight on N. side of Kilchiaran Bay (on S.E. side only).		200			$\frac{1}{4}$ " "	50	
do.	In cove near Eilean na Sgioba.						10	Just below ruined cottage.
do.	In creek just S. of Reidh a Bhuirg.						10	A few lbs. in other sheltered creeks.
do.	On rocks in Saligo Bay.						50	
do.	On S. side of Aird Thorr-innis.		50			$\frac{1}{4}$ -1 " "	40	
do.	Flat rocks S. of Port Bun Aibhne.		200			1 " "	200	Worth collecting also on skerries off shore.
do.	N. side of Port Bun Aibhne.		200			$\frac{1}{4}$ -1 " "	100	
do.	N.E. side of Sanaigmore Bay.		200			$\frac{1}{4}$ " "	50	Patchy.

TABLE V (contd.): OFFSHORE ISLANDS

ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT			NOTES		
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA		TOTAL WT. IN LBS.	
Gigartina do. do. do.	Islay (contd.) Rock in sandy bay just E. of Sanaigmore. S.W. of Cladach Fionn. N.E. of Cladach Fionn. Between Cladach Fionn and Carraig Bhan.	12				250 200 200 500	Fishermen say there are several hundred lbs. in Sanaigmore Bay, at a good ebb. Absent from steep or exposed rocks and present only in sheltered creeks where it may reach 2-3 lbs./lin. yd. Present thus on about 1/10 of coast. Present all the way and very rich in sheltered inlets. Varies from 1/4 to 3 or 4 lbs./lin. yd. Easily collected. Part could be harvested only by boat.	
	Carraig Bhan to Caves. From Eilean Nostaig along Traigh Nostaig. Leac Bhuidhe to Ardnave Pt.		900 800 1,760		1-2 " " 1 lb./lin. yd. 1/4 " "	1,300 880 440		
	Gigartina do. do. do. dc. do. do.		12	880 2,200 1,760 880 700 1,000 1,200	20	3 lbs./lin. yd. 1 lb./lin. yd. 5 lbs./lin. yd. 5 " " 10 " " 3 " " 1/4-1 lb./lin. yd.	2,640 2,200 8,800 4,400 7,000 3,000 900	Among <i>F. serratus</i> . Easily collected. Occurs on both sheltered and exposed sides of rocks. Richer (2-3 lbs./lin. yd.) round mouth of Doodilmore River. Especially rich in sheltered creeks.
				TOTAL WEIGHT FOR ISLAY IS 18.45 TONS.				
Gigartina do.		13					40 150	On five or six rocky tips. Steep parts of point have very little, less than 1/4 lb./lin. yd.
				JURA (surveyed July 1943). On Rudh 'an t-Sailein, rocky tips of point. On Rudha Liath and islands close to it.	600	Narrow	1/4 lb./lin. yd.	

TABLE V (contd.): OFFSHORE ISLANDS

		13		Narrow			In bays between these rocky points, there is nothing worth collecting.
Gigartina	Jura (contd.)	On Rudh' a Bhaillein.	200	Narrow	½ lb./lin. yd.	50	
do.		On Rudh a'Chrois-ainidh.	300	"	¼ " "	75	
do.		On Rudha Lang-ainidh.	350		1 " "	350	
do.		On Rudh 'Aird na Sgitheich.	500		½ " "	125	
do.		On islands offshore at Rudh' Aird na Sgitheich.	600		1 " "	600	
do.		Rocks opposite Clach na Gile.	150		¾ " "	40	
do.		Southernmost point of Brein Phort.	300		¾ " "	75	
do.		On Rudha Aoineadh an Reithe.	300		¾ " "	75	
do.		On Rudha Barr nan Gobag.	300		¾ " "	75	
do.		On rocks on W. side of Jura House bay.	25		½ " "	12	
do.		On W. side of Rudha na h-Acairseid.	200	Narrow	¾ " "	50	
do.		In Port nan Cladan.				20	
do.		On three rocks at head of Loch na Mile.				20	
do.		On tip of Rudha Bhrìde.				10	
do.		From 600 yds. N. of An Dunan to S. point of Port an Ainidh Uir.	750	Narrow	¾ " "	375	Could be harvested only from a boat.
do.		N. of Port-an Ainidh Uir to Port an Fhiurain.	1,000	"	1-½ " "	400	
do.		N. of Port an Fhiurain to Port an Doire Dharaich.	1,000	"	¾ " "	250	
do.		On rocks S. of Tarbert Bay.	350	"	¾ " "	90	
do.		N. of Tarbert Bay.	1,760	"	¾ " "	440	Richer just N. of Tarbert Bay. There may be more at a very good ebb. TOTAL WEIGHT FOR JURA IS 1·5 TONS.
Gigartina	COLONSAY AND ORONSAY (surveyed July 1943).	From Scalasaig jetty, to sand in Loch Staosnaig.	1,400	Fairly narrow	½ lb./lin. yd.	700	Varies up to 2 lbs./lin. yd.
do.		S. side of L. Staosnaig, to sandy bay N. of Rudha Dubh.	1,760	Fairly wide	1 " "	1,760	Richest on S. side of L. Staosnaig, where it is 2 lbs./lin. yd., and poorest on Rudha Eileann Mhartain. Quality poor.
do.		½ mile N. of Meall an Arbhair, to Meall an Arbhair.	880		¾ " "	220	Richer (¾ lb. /lin. yd.) on two points just N. of Meall an Arbhair.
do.		On outside of rocky point S. of Eilean Treadhrach.	1,200	20-30	4-5 lbs./lin. yd.	5,400	
do.		Round Rudha Caol and Eilean Trainaig.	2,300		3-4 " "	8,000	
do.		Round Eilean nan Uan.	1,760		½ lb./lin. yd.	880	} Probably present also on islands off shore.

TABLE V (contd.): OFFSHORE ISLANDS

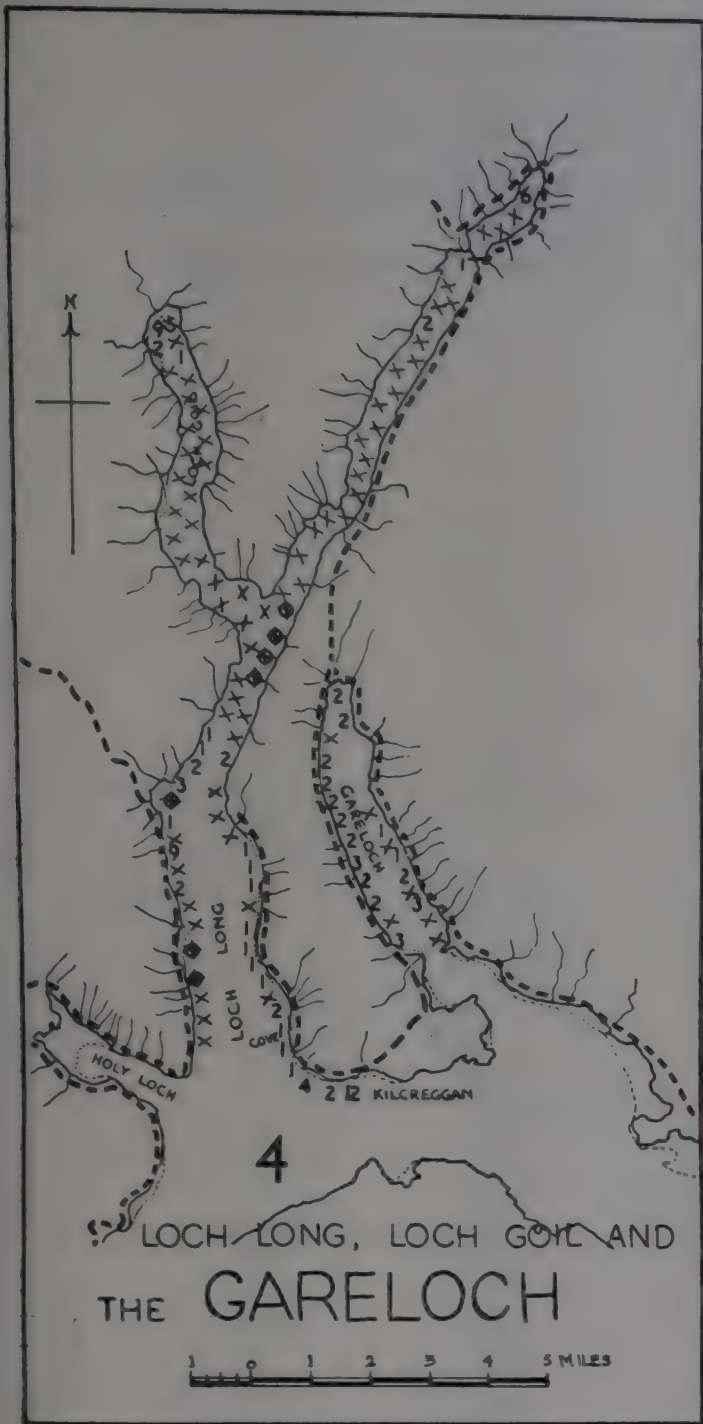
ALGA	LOCALITY	MAP	ESTIMATE OF WEIGHT			NOTES
			DISTANCE IN YARDS	WIDTH OF ZONE IN YARDS	WEIGHT OF ALGA	
		14				
Chondrus	Colonsay and Oronsay (contd.)					
do.	In Port nan Luinge.		1,760		$\frac{1}{4}$ - $\frac{1}{2}$ lb./lin. yd.	
Gigartina	S. side of Abhainn a Chuirn.		880		$\frac{1}{4}$ " "	Islands off shore may be rich.
do.	On Plaidhe Mhor.		250		1 " "	Difficult to collect.
do.	Round Turnigil Point.		880		1 " "	
do.	N. side of Port Lobh.		300		1 " "	
Gigartina and Chondrus						
do.	Rocks on S. side of Tobar Fuar Bay.		50		6-7 lbs./lin. yd.	
Gigartina	Rocks on N. side of Tobar Fuar Bay.		200		$\frac{1}{4}$ - $\frac{1}{2}$ lb./lin. yd.	
do.	In Port an Tighe Mhoir.					Poor material, in small tufts.
do.	S.W. side of Kiloran Bay.					Rather scattered.
do.	Just S. of Port na Cuilce.					
Chondrus	In Port na Cuilce.		20		2 lbs./lin. yd.	
Gigartina	In S.W. corner of Poll Ban.					Most easily collected by boat. Mixed with Leathesia.
do.	In creeks between Rudha na Lice Buidhe and Balnahard Bay.					Present in creeks and at heads of small bays, but not worth collecting on the headlands between.
do.	Islands on N. side of Balnahard Bay.					On landward side.
do.	Rocks in middle of Balnahard Bay.					
do.	On S. side of Balnahard Bay to Rudh' a' Geodha.					1-2 lbs./lin. yd. in places.
do.	Creek at tip of Rudh' a' Geodha.					
Chondrus	Inlet just S. of Port Ceann a Gharraidh.					
Gigartina	Between Rudha Carraig nan Darrach and Rudha Garbh.		50		1 lb./lin. yd.	In a sheltered cove.
do.	For 250 yds. S. from Rudha Garbh.		250		1 " "	
do.	S. side of Port a' Bhata.		100	10	$\frac{1}{4}$ " "	
do.	From Rudha Mor to Rudha an Dobhrain.		700	10	$\frac{1}{4}$ lbs./lin. yd.	Improves up to 3 lbs./lin. yd. on Rudha Mor.
do.	N. of Scalasaig jetty.		200		1 lb./lin. yd.	
						TOTAL WEIGHT FOR COLONSAY AND ORONSAY IS 9.9 TONS.

M A P S

**MAP 1**

The general distribution of large harvestable areas of *Gigartina stellata* Batt. and *Chondrus crispus* (L.) Stackh. in Great Britain. (N. Ireland and the Isle of Man excluded)

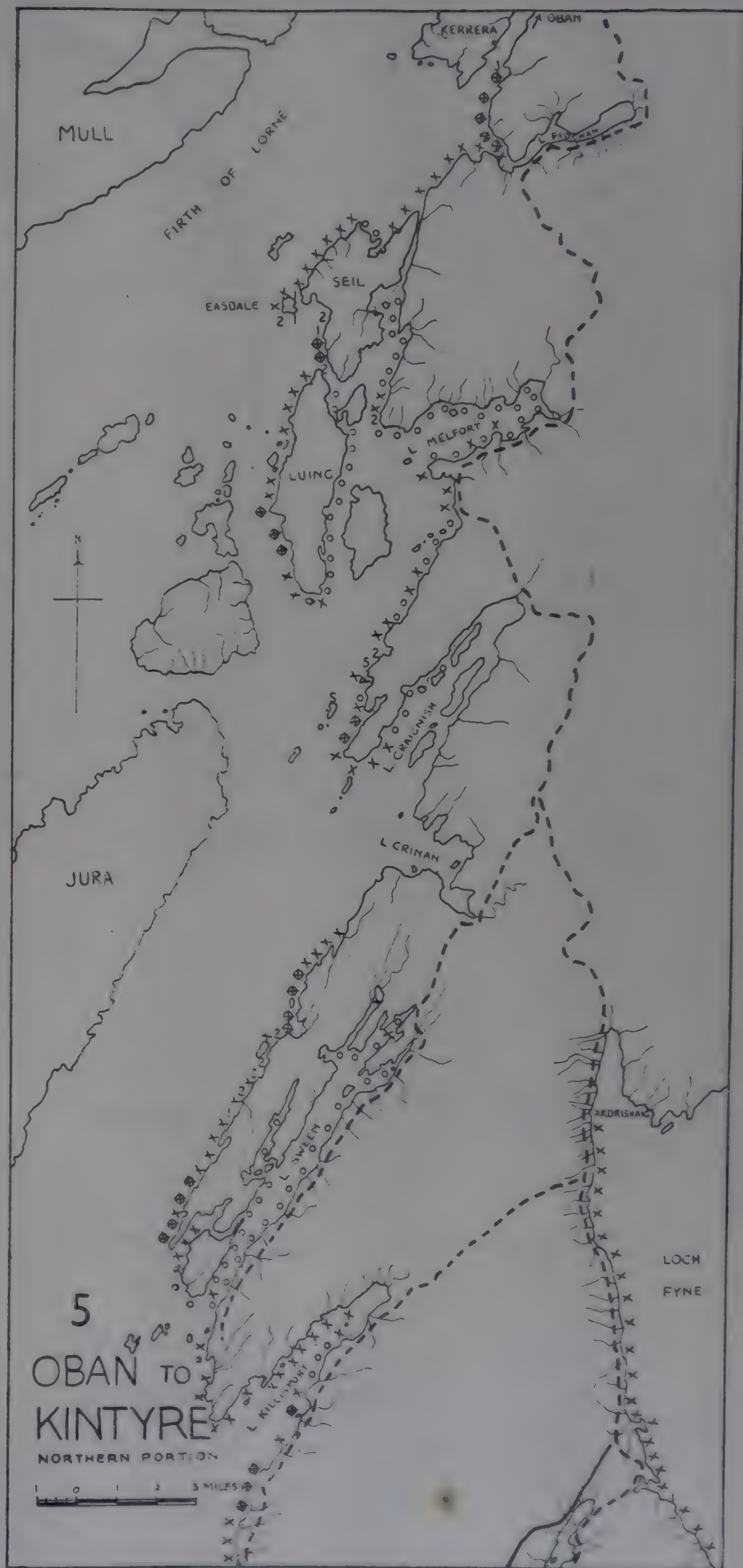
- (1) Skye and its associated islands
- (2) Mull
- (3) Coast from Ardrossan to Oban including adjacent islands
- (4) Coast of Ayrshire and Wigtownshire
- (5) Anglesey
- (6) The Lleyn Peninsula
- (7) South coast of Cardigan Bay
- (8) St. David's Head
- (9) The Gower Peninsula
- (10) Devon and Cornwall
- (11) South-east Scotland and north-east England
- (12) Tiree



MAP 4

LOCH LONG, LOCH GOIL AND THE
GARELOCH (CLYDE SEA-AREA)
showing the distribution of *Gigartina* in lbs.
per linear yard

For explanation of symbols see Map 2



MAP 5

MAINLAND COAST FROM OBAN TO
NORTH KINTYRE (ARGYLLSHIRE)
showing the distribution of *Gigartina* and
Chondrus in lbs. per linear yard

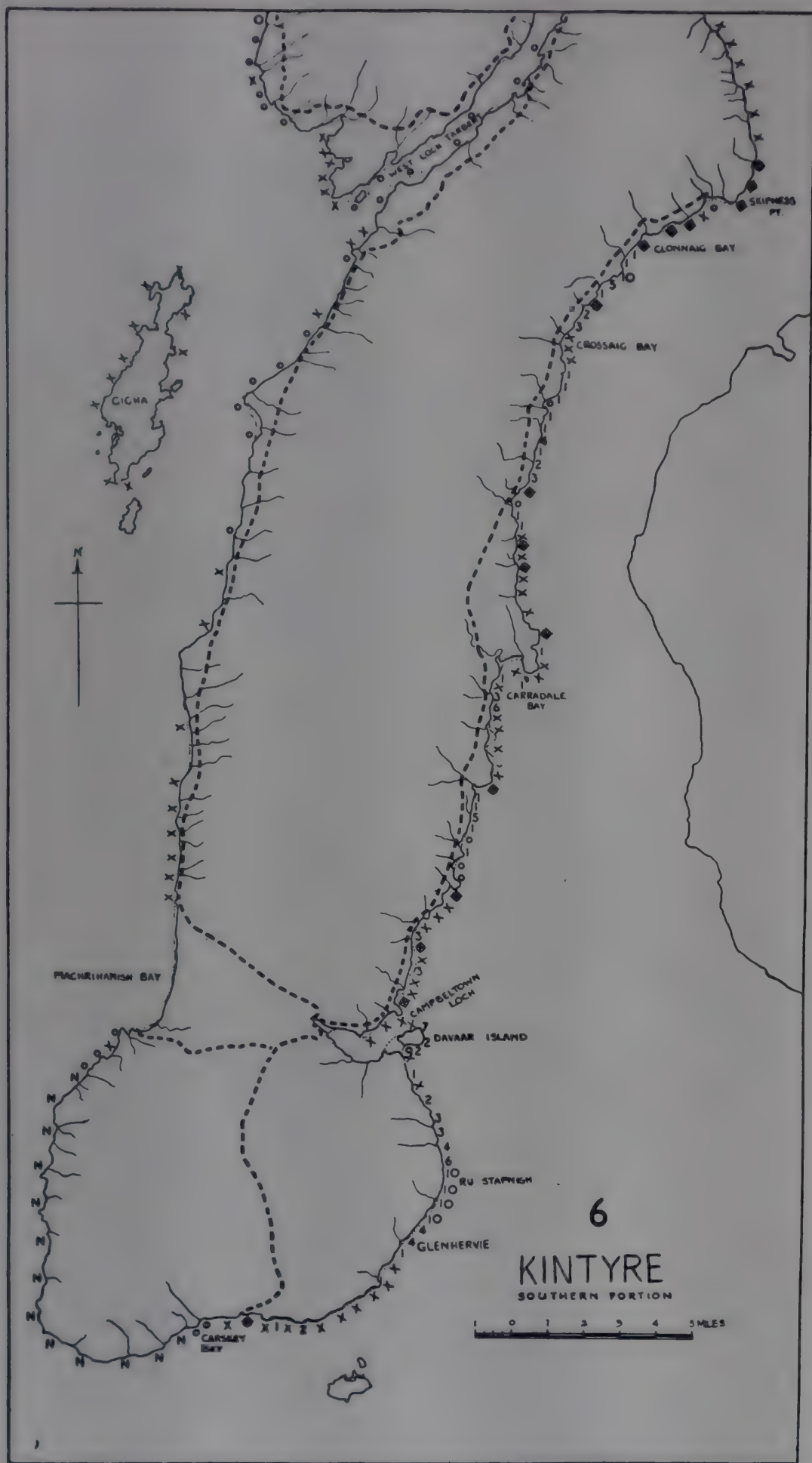
For explanation of symbols see Map 2

MAP 6

KINTYRE PENINSULA

showing the distribution of *Gigartina* in lbs.
per linear yard

For explanation of symbols see Map 2

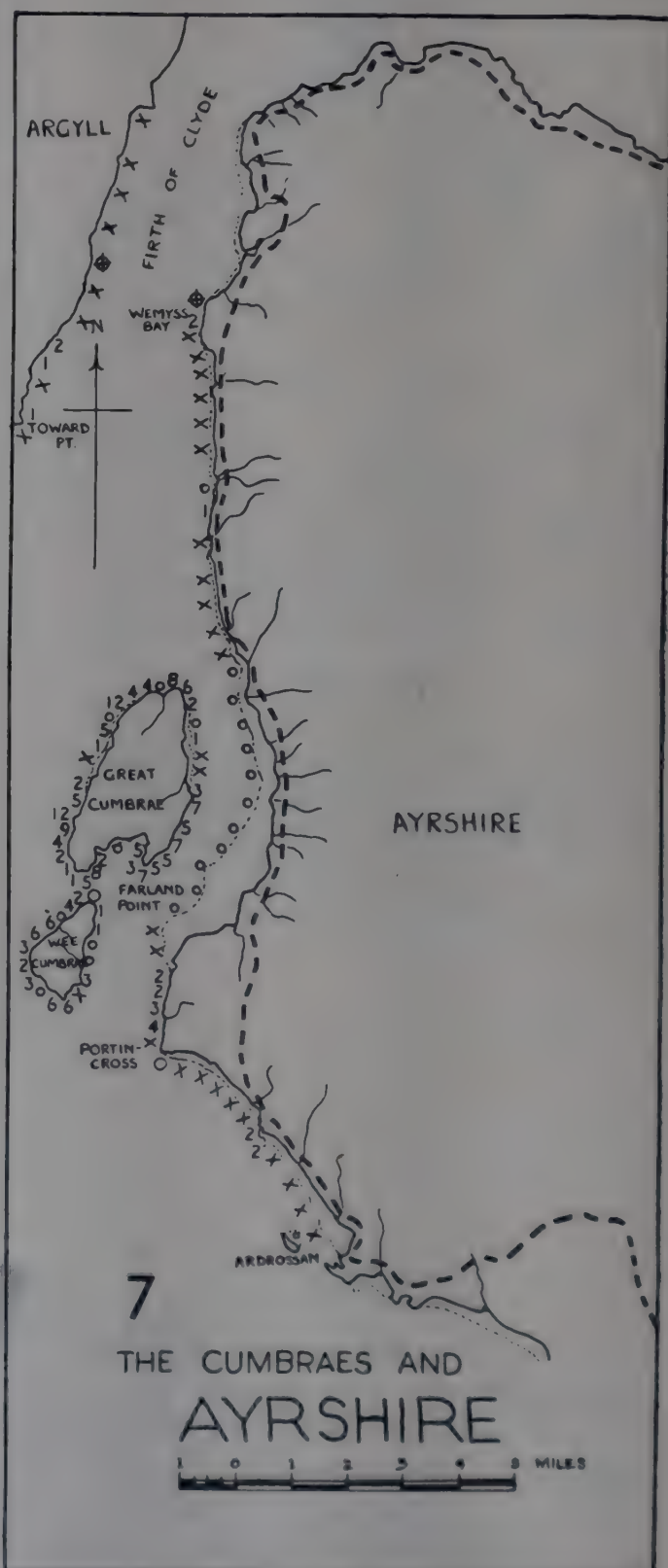


MAP 7

AYRSHIRE COAST FROM WEMYSS BAY
TO ARDROSSAN, WITH THE CUM-
BRAES AND PART OF THE COWAL
SHORE

showing the distribution of *Gigartina* in lbs.
per linear yard

For explanation of symbols see Map 2





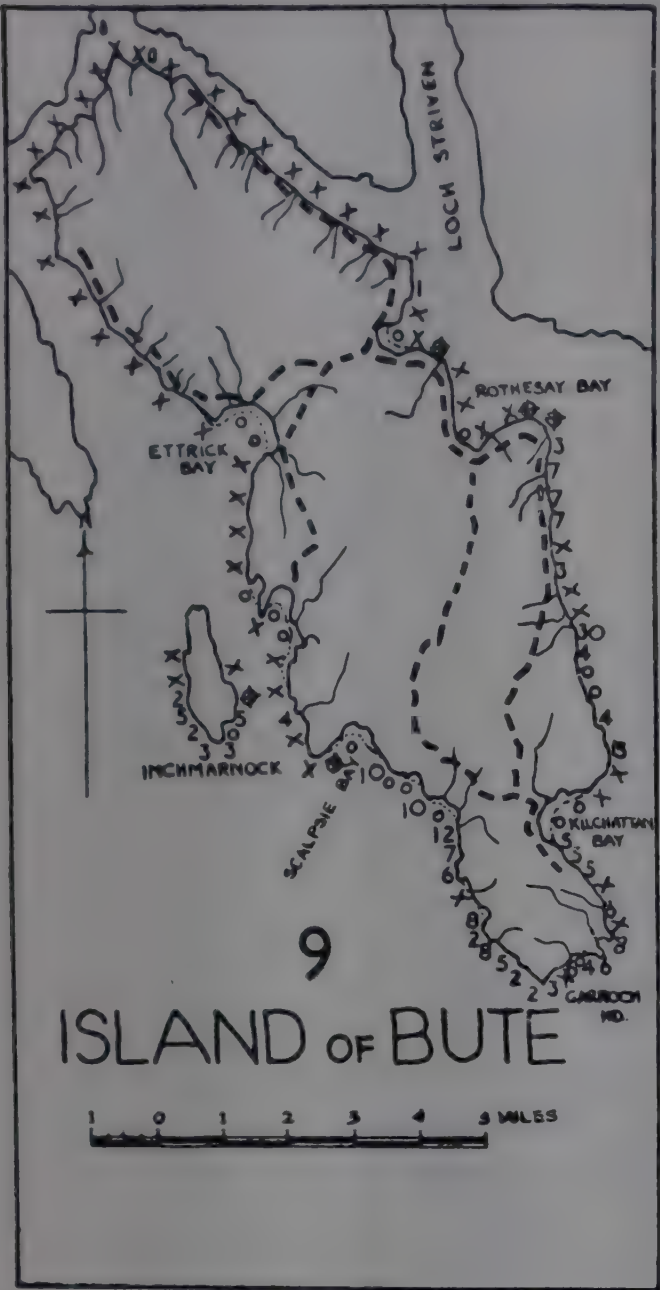
AYRSHIRE AND WIGTOWNSHIRE

THIS AREA WAS SURVEYED BY A DIFFERENT METHOD FROM OTHER AREAS. (SEE P.8.) THE FIGURES REPRESENT THE TOTAL ESTIMATED WEIGHT IN LBS. (BASED ON QUANTITY PER SQ. YD.)

--- ROADS

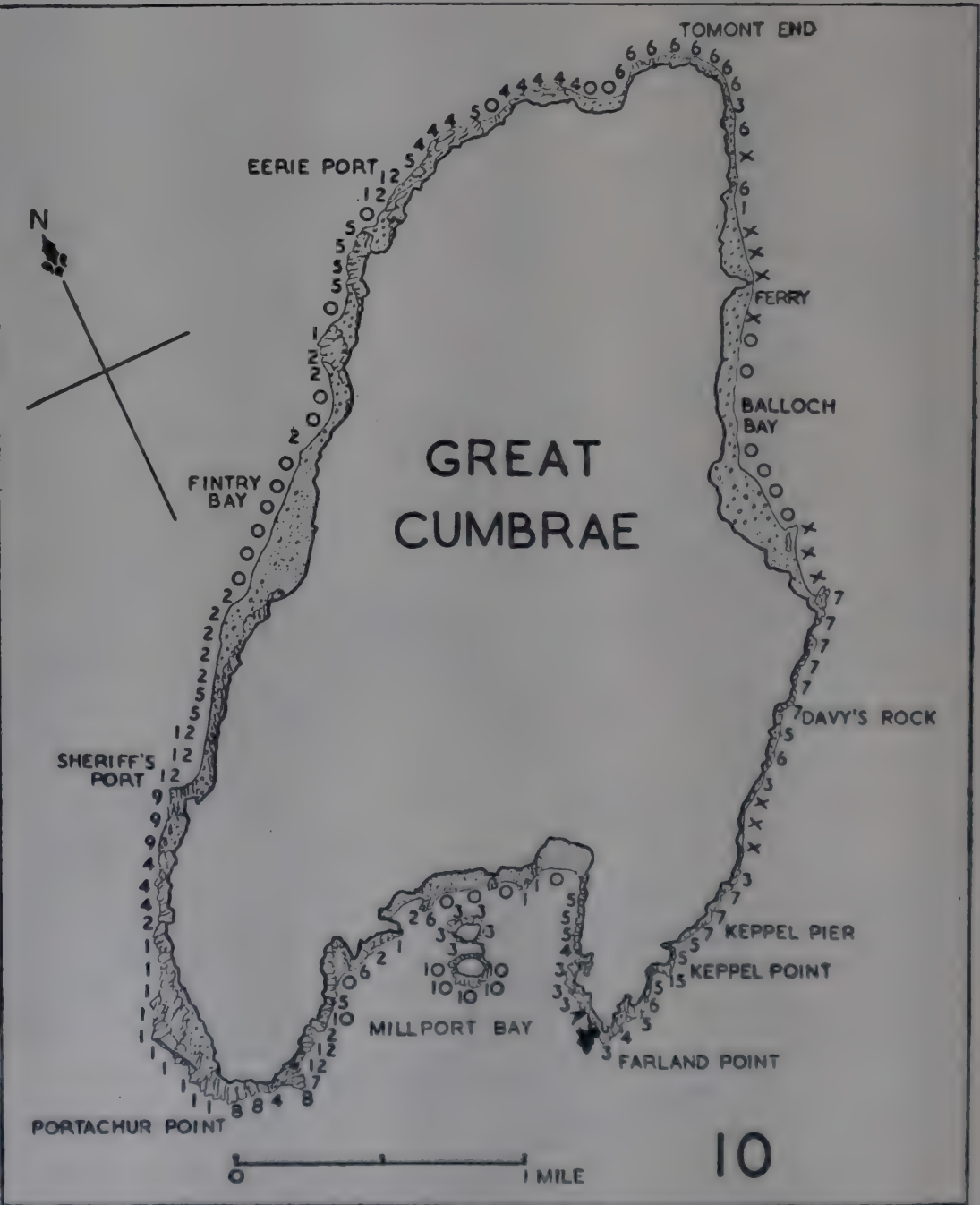
MAP 8

AYRSHIRE AND WIGTOWNSHIRE COAST: WRIGHT'S ISLAND TO BURROW HEAD showing the distribution of *Gigartina* and *Chondrus*



MAP 9

BUTE
showing the distribution of *Gigartina*
and *Chondrus* in lbs. per linear yard
For explanation of symbols see Map 2



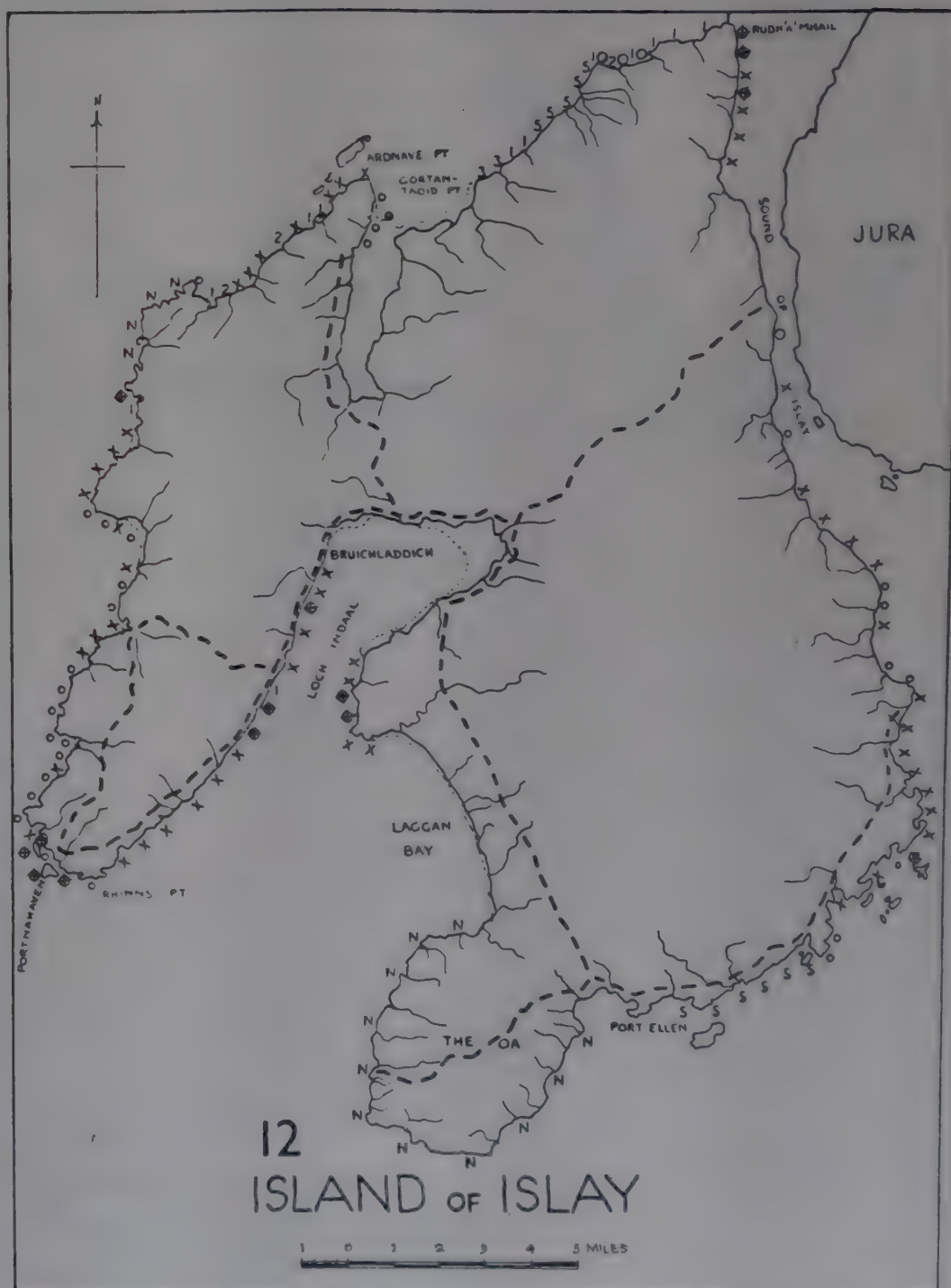
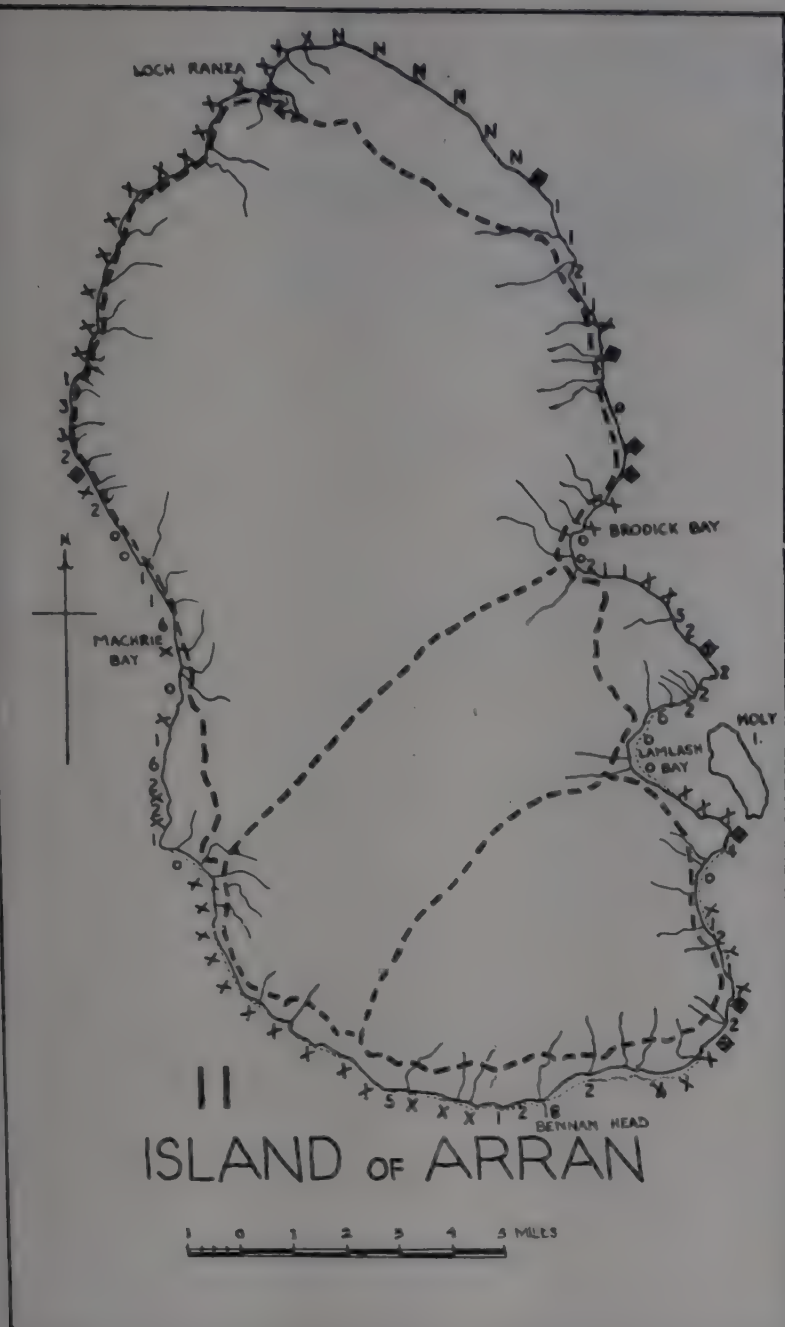
MAP 10

GREAT CUMBRAE
showing the distribution of *Gigartina*
in lbs. per linear yard
For explanation of symbols see Map 2

MAP 11

ARRAN

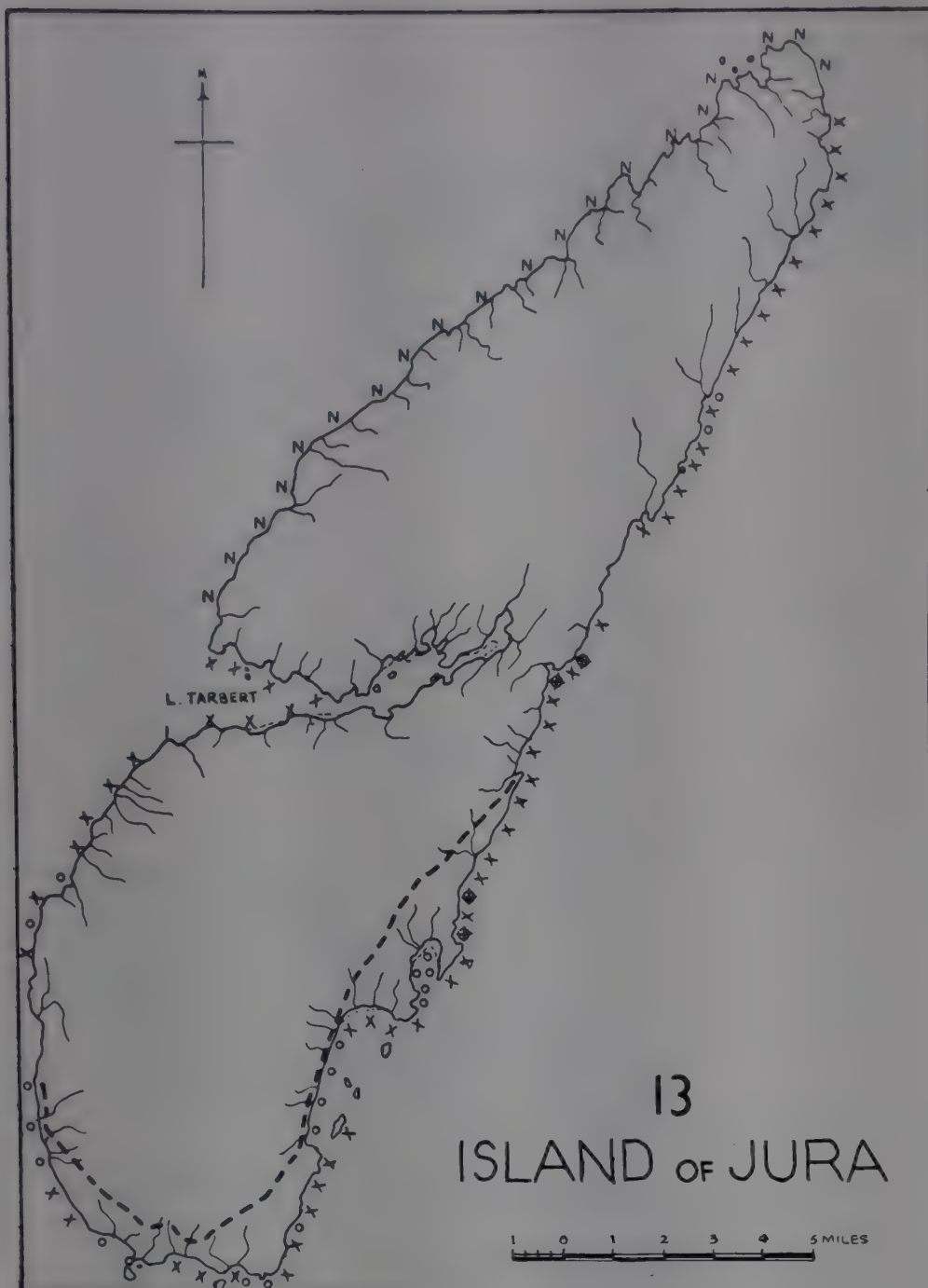
showing the distribution of *Gigartina*
and *Chondrus* in lbs. per linear yard
For explanation of symbols see Map 2



MAP 12

ISLAY

showing the distribution of *Gigartina*
and *Chondrus* in lbs. per linear yard
For explanation of symbols see Map 2



MAP 13

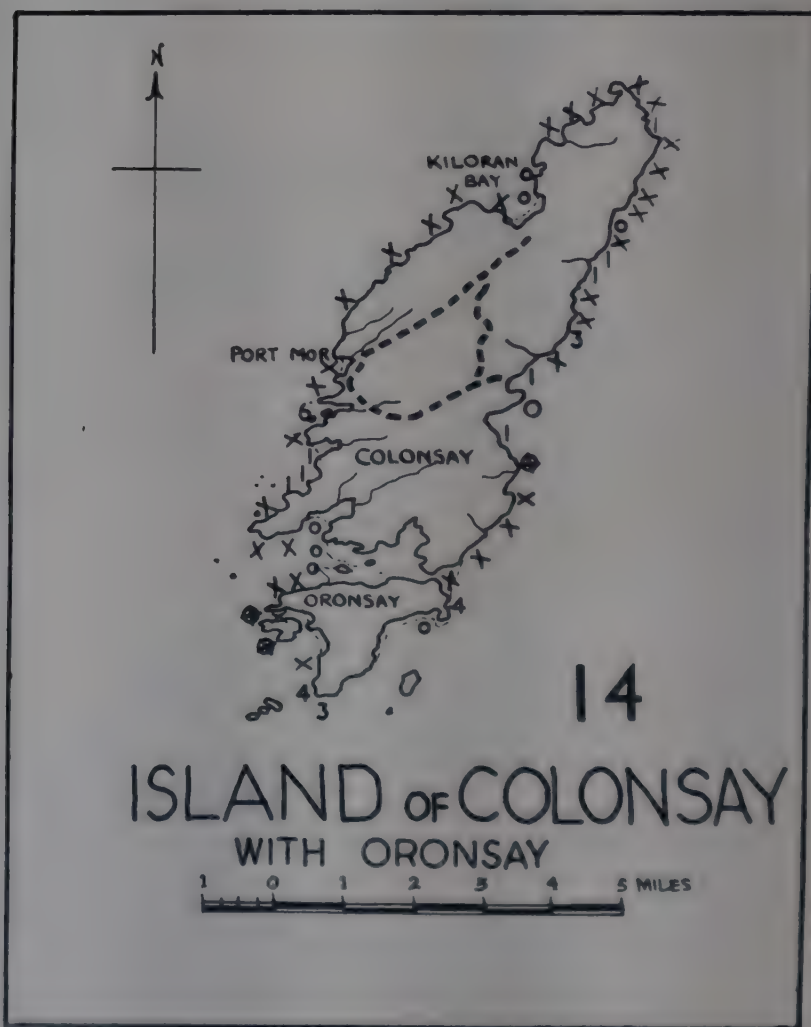
JURA

showing the distribution of *Gigartina*
in lbs. per linear yard

For explanation of symbols see Map 2

13
ISLAND OF JURA

1 0 1 2 3 4 5 MILES



MAP 14

COLONSAY AND ORONSAY

showing the distribution of *Gigartina*
and *Chondrus* in lbs. per linear yard

For explanation of symbols see Map 2

14
ISLAND OF COLONSAY
WITH ORONSAY

1 0 1 2 3 4 5 MILES

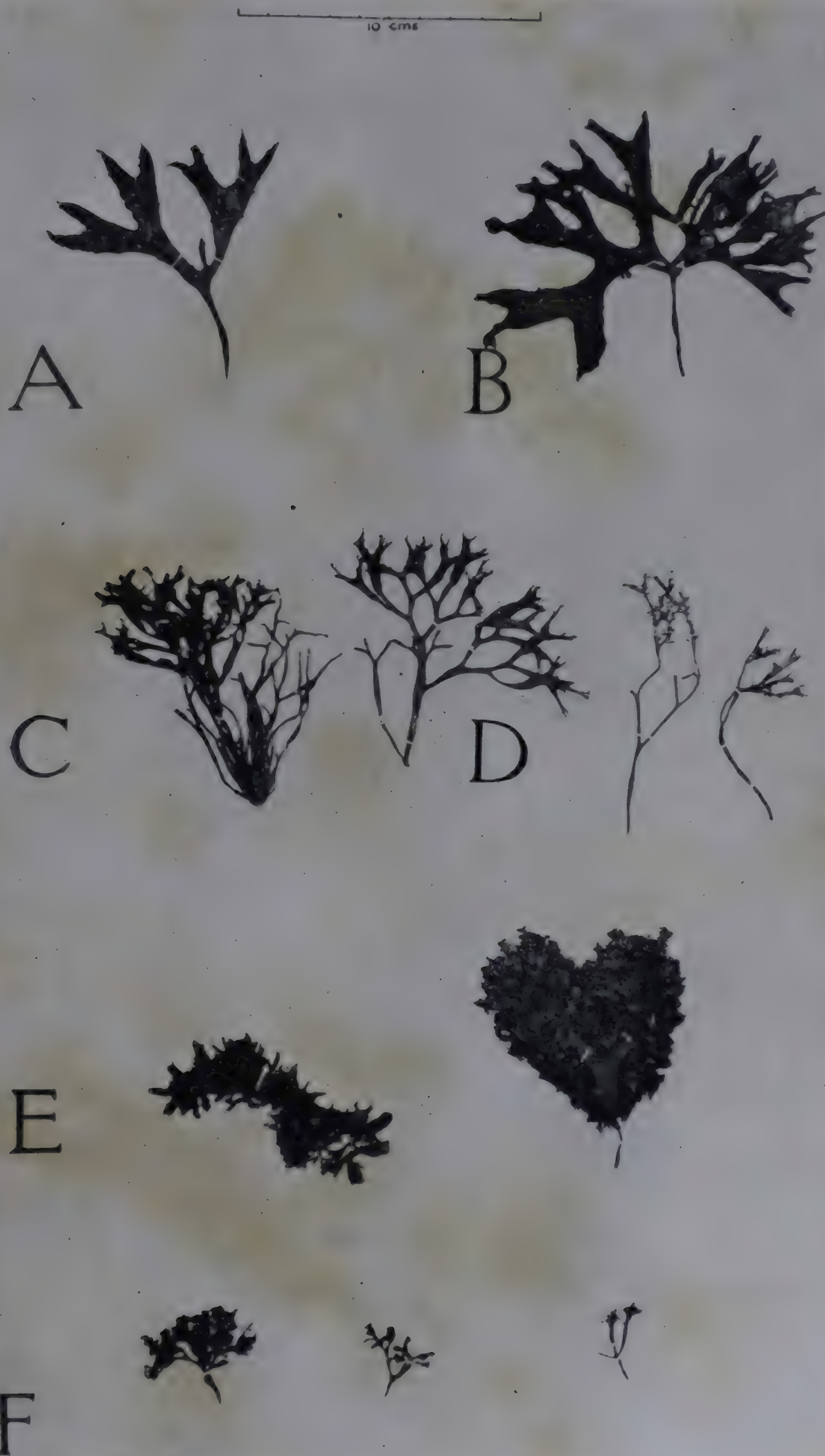
P L A T E S

PLATE I

Gigartina stellata Batt.

:

ILLUSTRATING RANGE OF FORM AND VARIETIES



A & B. *Gigartina stellata* Batt.

A. Specimen from Aberdaron, Llyn Peninsula (October 1943).

B. Specimen from Cumbrae: *Gigartina-Cladophora* community (July 1944).

The branching is regularly dichotomous and the papillae almost completely cover the expanded surface of the thallus.

C & D. *Gigartina stellata* var. *acuta* Good. & Woodw.

C. Specimen from Overton, Gower (January 1943).

D. Specimen from Llanon, Cardiganshire; on sand in a *Fucus serratus* community (August 1942).

This shows the linear papillae, at the tips of which the spermatangia are developed.

E. *Gigartina stellata* Batt.

'Parsley' forms from the *Fucus vesiculosus* community at Aberayron. Both specimens are extreme forms (August 1944).

F. *Gigartina stellata* Batt.

Dwarf forms. Found under the splash of fresh water from the promenade wall at Aberystwyth.

PLATE II

Gigartina stellata Batt. : PLANTS GROWING UNDER DIFFERENT ENVIRONMENTAL CONDITIONS



A. From Horton, Gower

- (1) A perennial plant from the sub-littoral zone, bearing epiphytes, especially *Membranipora pilosa*. This type of plant is still shedding spores after the plants higher up the shore have been torn away by autumn gales.
- (2) A typical pseudo-perennial plant from the *Gigartina-Lomentaria* community in the lower littoral zone.

B. From Aberayron

- (1) A plant from a shingle pool near low water mark.
- (2) A plant from the shingle higher up the shore.

C. From Aberystwyth

- (1) & (2) Plants from beneath the thalli of *Fucus serratus*.
- (3) & (4) Plants 9 months after the overlapping seaweeds had been removed.

D. From Bull Bay, Amlwch

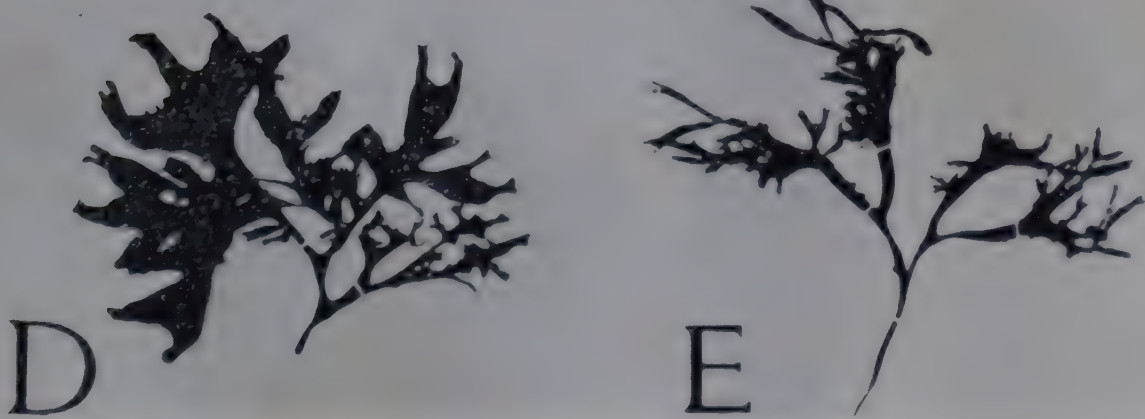
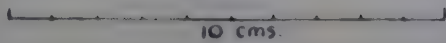
- (1) Plant from a control area.
- (2) 6 months after the overlapping weeds had been removed.

PLATE III

Gigartina stellata Batt.

:

STAGES IN THE DEVELOPMENT OF THE THALLUS



A. Young thalli from Aberystwyth and the Cumbrae, recognisable only by the channelled frond.

B. Specimens from Aberporth showing the new vegetative growth in spring (May 1944).

- (1) A new frond which has arisen from the holdfast.
- (2) An old thallus with new marginal growth.

C. Thallus with young linear papillae in which the spermatangia and carpogonial branches are developing: Aberystwyth (March 1943).

D. Thallus in summer with well developed papillae containing cystocarps. The older part of the thallus to the right is in marked contrast to the current season's growth on the left: Cumbrae (July 1944).

E. The thallus after the cystocarps have matured and probably have shed their spores: Aberdaron (October 1942).

PLATE IV

GIGARTINA GERMLINGS GROWING
IN CULTURE MEDIUM: ABOUT THREE
WEEKS OLD
× 150

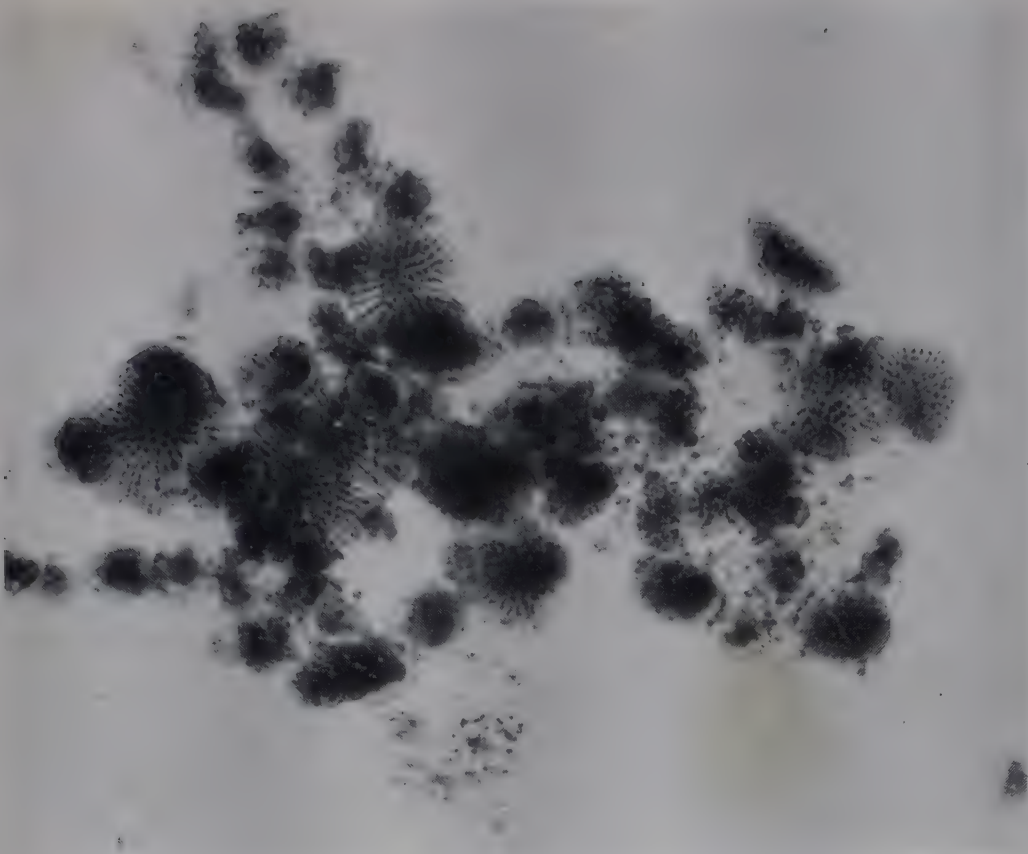


PLATE V

RECOLONISATION
(Keppel Point, Cumbrae)

A. A metre quadrat cleared by scraping in June 1943. Photograph taken November 1943; showing a low growth of *Gigartina* covering almost all of the plot.



B. A similar metre quadrat cleared by scraping in June 1943 and photographed in July 1944. The right hand corner of the quadrat lies at the point X.



PLATE VI

RATE OF RECOLONISATION (KEPPEL POINT, CUMBRAE)



A. A metre quadrat cleared by scraping March 19th 1946. Photograph taken June 6th 1946 ; showing 'mat' of *Cladophora rupestris* and *Enteromorpha Linza*. The metal disc is 2" in diameter.

· Photographs B & C of
Plate VI are overleaf

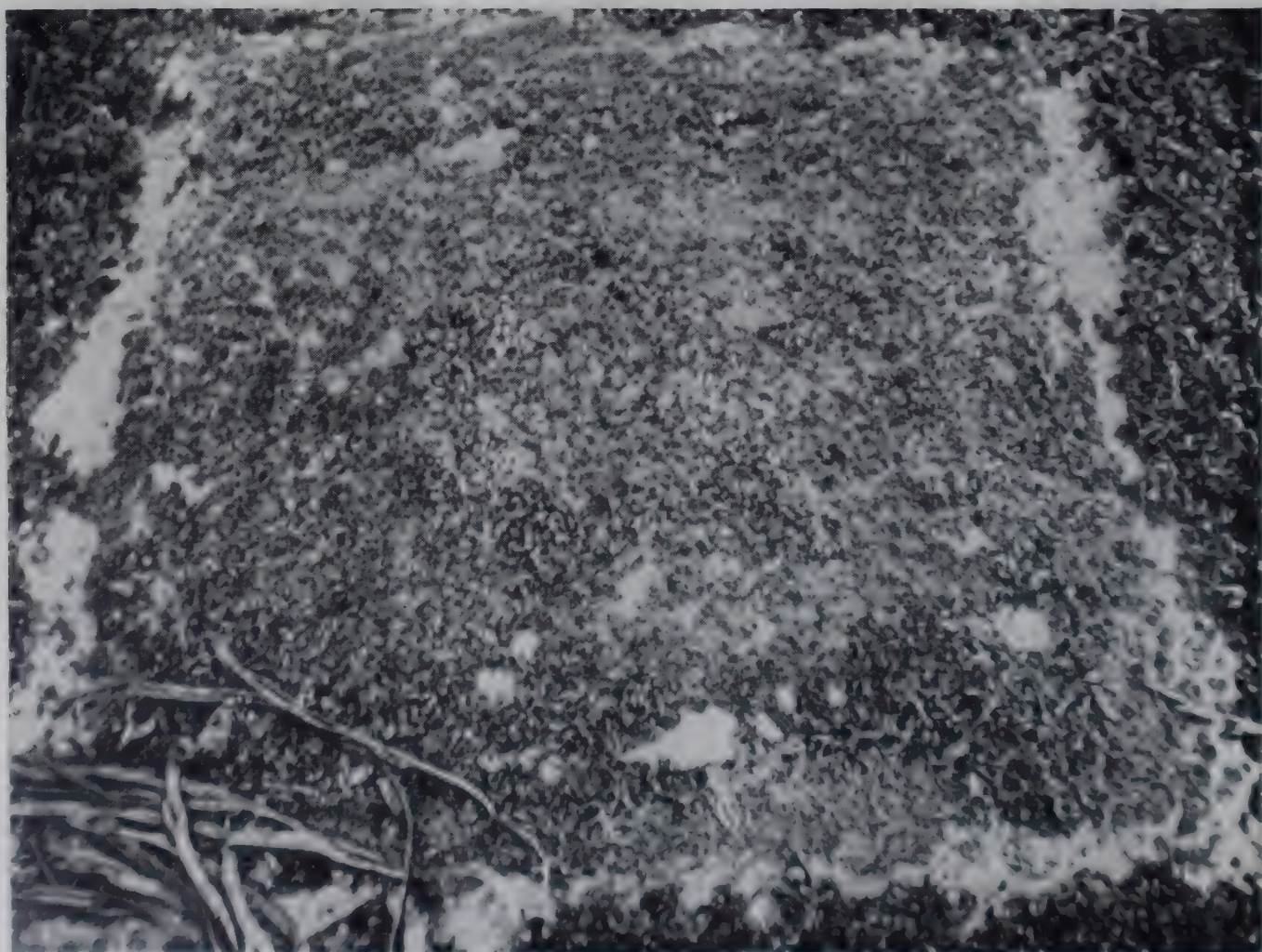
PLATE VI

(continued)

RATE OF RECOLONISATION (KEPPEL POINT, CUMBRAE)



B. Photograph taken August 15th 1946. Green weeds receding and low growth of *Gigartina* visible



C. Photograph taken October 20th 1946. Green weeds have almost disappeared and quadrat is becoming covered by a thick growth of *Gigartina* plants from 0.5 to 1.0 cm. in length. (A 4" band has been newly scraped around the quadrat)

PLATE VII



GIGARTINA BELT AT KEPPEL POINT, CUMBRAE

PLATE VIII



THE TWO ROCKS IN THE FOREGROUND SHOW LIMPET GLADES. THE ROCK IMMEDIATELY BEHIND HAS BEEN RECOLONISED BY GIGARTINA AFTER THE REMOVAL OF THE LIMPETS (KEPPEL POINT, CUMBRAE)

PLATE IX



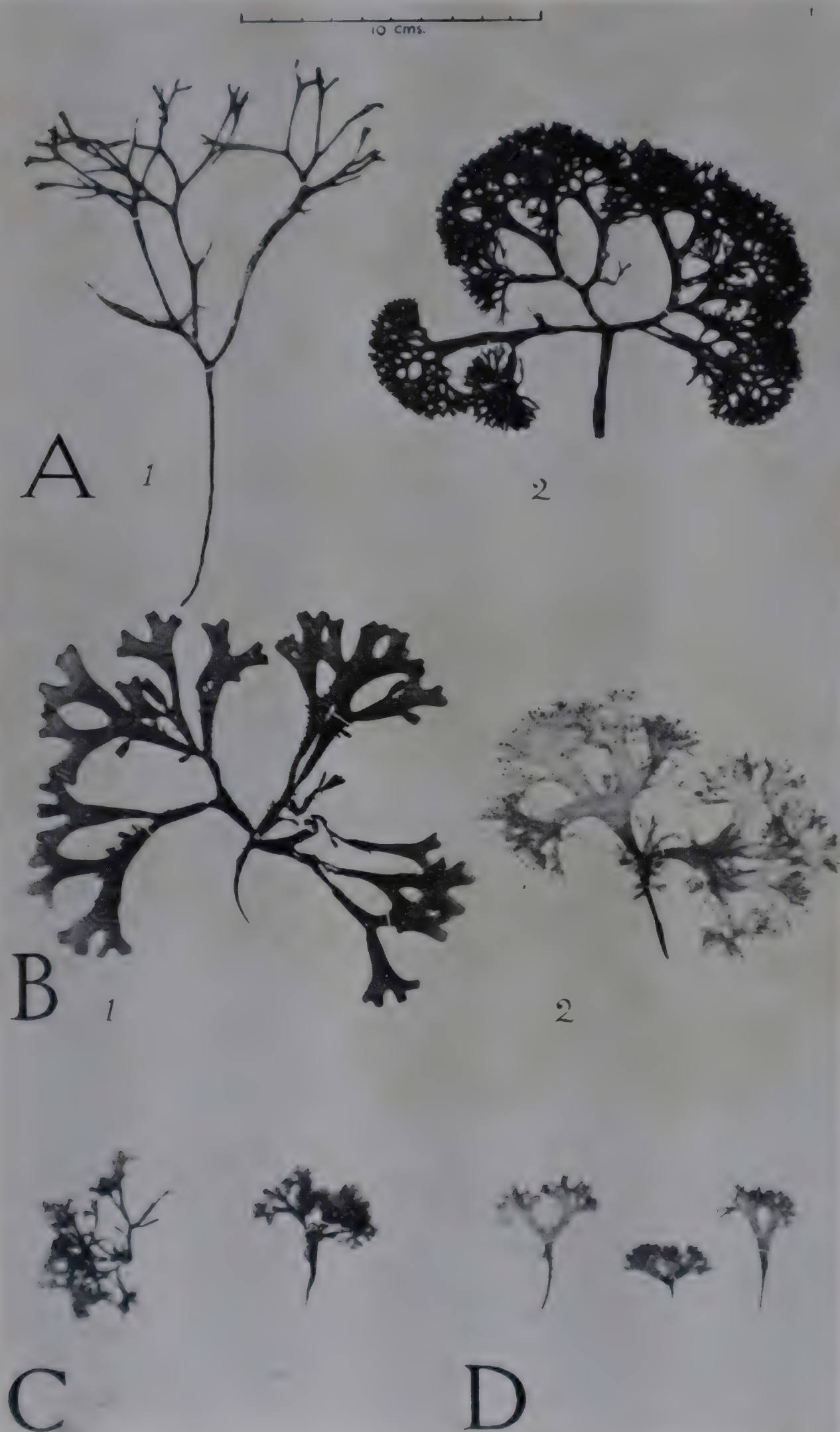
CHONDRUS CRISPUS VAR. FILIFORMIS TURN. $\times \frac{3}{5}$

Sub-littoral zone, Aberayron

PLATE X

Chondrus crispus (L.) Stackh.

ILLUSTRATING RANGE OF FORM



A. Var. *aequalis* Turn.

- (1) Specimen from sub-littoral zone at Aberayron (April 1944).
- (2) Broader form from sub-littoral zone at Aberayron (November 1942).

B. (1) Var. *stellatus* Turn.

From intertidal shingle pool at Aberayron (June 1944).

(2) Type species.

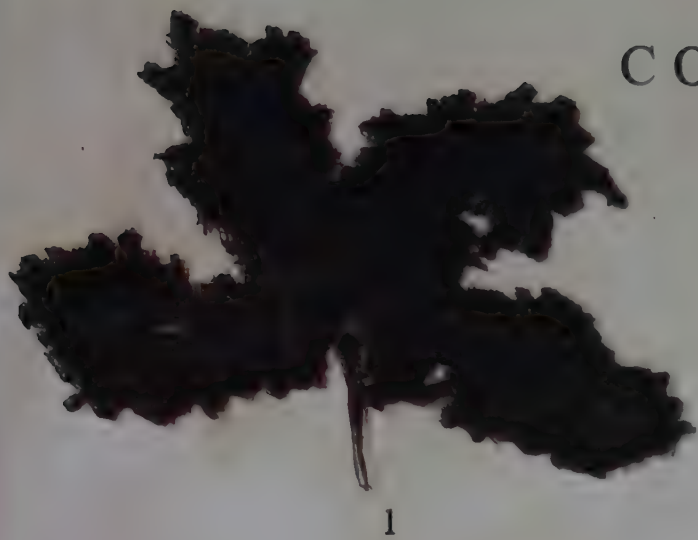
Cystocarpic plant from intertidal shingle pool at Aberayron (August 1944).

C. Dwarf form of the type species. From shingle beach at Aberarth (June 1942).

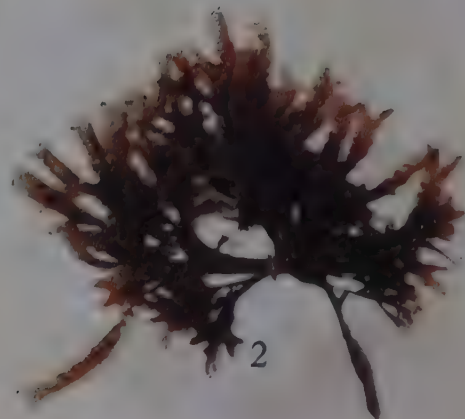
D. Plants found growing in rock pools near high water mark at Aberystwyth (July 1944).

COLOUR PLATE I

Gigartina stellata Batt.



1



2



3



4



5

About one-third natural size

(1) Specimen from the *Fucus vesiculosus* association Aberayron, Cardiganshire (August 1942).

(2) Specimen from the *Fucus vesiculosus* association Aberarth, Cardiganshire (June 1942).

(3) Specimen from the *Fucus serratus* association Llanon, Cardiganshire (August 1942).

(4) Specimen from the *Fucus serratus* association Aberdaron, Llyn Peninsula (October 1943).

(5) Specimen from the *Gigartina* association Aberporth, Cardiganshire (April 1944).

(This shows the new growth at the thallus tips in spring).

COLOUR PLATE II

Chondrus crispus (L.) Stackh.



About one-third natural size

(1) & (5) Specimens from the *Fucus serratus* association Rhoscolyn, Anglesey (August 1942).

(2) Specimen from a shingle pool near H.W.O.S.T. at Aberarth, Cardiganshire (June 1942).

(3) Specimen from the sub-littoral zone Aberystwyth, Cardiganshire (October 1944).

(4) Specimen from the shingle pools in the inter-tidal belt at Aberayron, Cardiganshire (August 1944).

(6) Specimen from a rock pool in the inter-tidal belt at Aberystwyth, Cardiganshire (October 1942).

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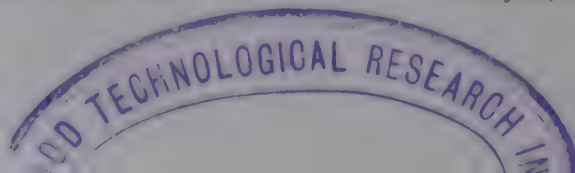
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